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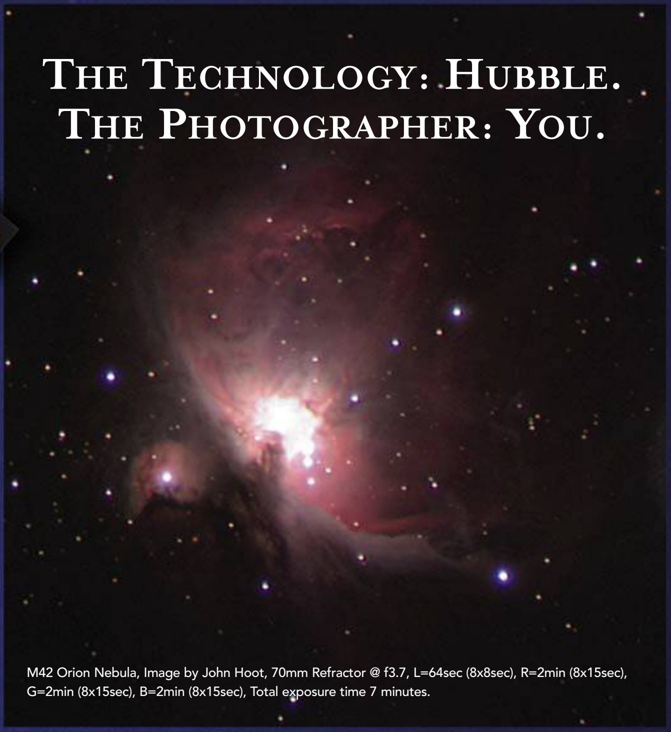

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LYNETTE COOK

ON THE COVER

It's like another solar system within our solar system. The Sun's planet family has much variety, from baked worlds to frozen ones. But for real diversity, check out those 141 moons! Space artist Lynette Cook took on the challenge of capturing these moons in their multitudes — how many can *you* identify?

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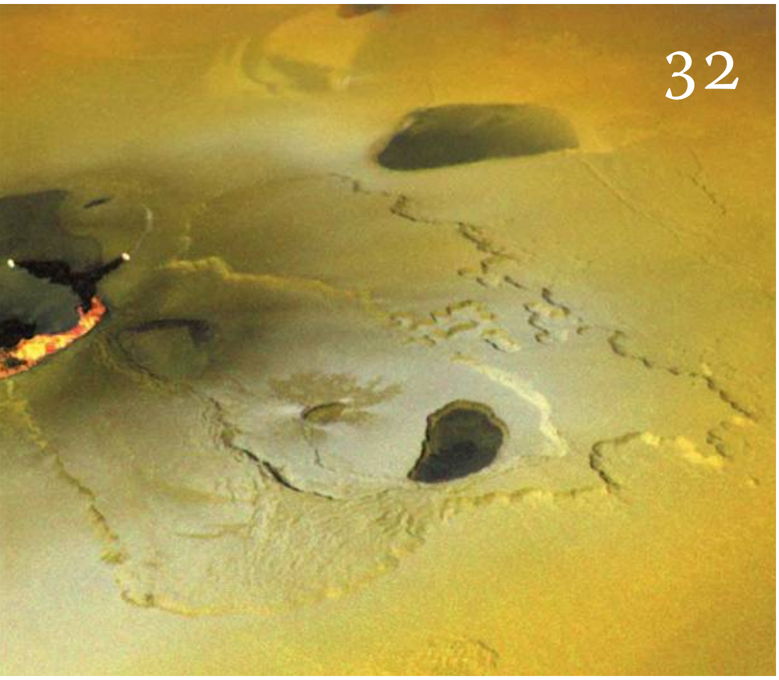

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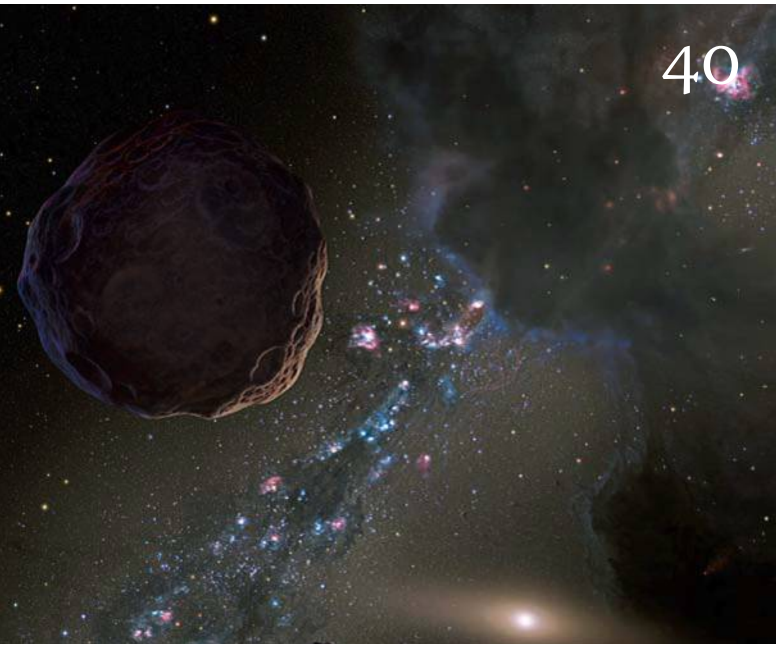

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{ THIS MONTH IN *ASTRONOMY* }

BY DAVID J. EICHER

Too many moons

When you hear the word "moon," you probably think of Earth's moon — *the Moon*. But at least 140 other moons orbit the planets in our solar system. Jupiter leads the pack with 63. ☾ Each moon is a unique world; each a different sort of place than the steel gray, battered lunar surface we see revolving around our planet. They range from Ganymede, Jupiter's largest moon, spanning more than 3,200 miles (5,150 km) across, to small fragmentary rocks from ancient collisions.

In "Mysterious microworlds" (page 32), British science journalist Jacqueline Garget introduces us to the immense variety of moons and how they help astronomers understand the solar system. Nearly all of the 141 known moons fit into one of four distinct categories.

In the first, Jupiter's Io, a uniquely volcanic world, stands alone. Second is the group of icy volcanic moons that includes Europa, Enceladus, Ganymede, and Miranda. "Target worlds" — those heavily affected by impact craters — include Callisto, Dione, Iapetus, and Phoebe.

Lastly, the "weird worlds" give us a heavy mixture of volcanism and impacts. Among them are Titan and Triton — the only moons with substantial atmospheres — and Earth's Moon.

Despite the great numbers of moons, only recently have astronomers been able to build detailed descriptions of them. Spacecraft imaging shows us they have a variety of characteristics. Temperatures range from lava erupting on Io at 3,600° F (1,980° C) to a frozen surface on Triton of –391° F (–235° C) — making it the coldest body in the solar system.

Shapes range from Earth's round Moon to such lumpy, bizarre structures as Saturn's Phoebe, which has been hit so many times it contains craters on top of craters. Some moons are frozen in time, like Jupiter's Callisto, which has a heavily cratered surface that hasn't changed in billions of years. Other moons, however, have dynamic systems occurring that reshape their surfaces. Miranda, which belongs to Uranus, has a jumbled texture of both smooth and heavily reworked terrain. How does a world grow only halfway and then stop evolving?

Over recent years, many have speculated on the possibility of life existing on one or more moons of the solar system. Assuming that life needs liquid water — a reasonable assumption when one looks at our home planet — then the likeliest place for it would be a subsurface ocean on Europa or water trapped under Titan's icy crust. "Europa's surface looks like broken glass stuck together with icy glue," writes Garget, "tidal stresses open cracks continually and sheets of icy crust creep and then freeze together again." The best reason for this would be a slushy ocean under the ice.

It's just one of many such amazing places you'll find in Garget's article, as you journey to see a solar system you might not know exists.

Yours truly,

David J. Eicher
Editor

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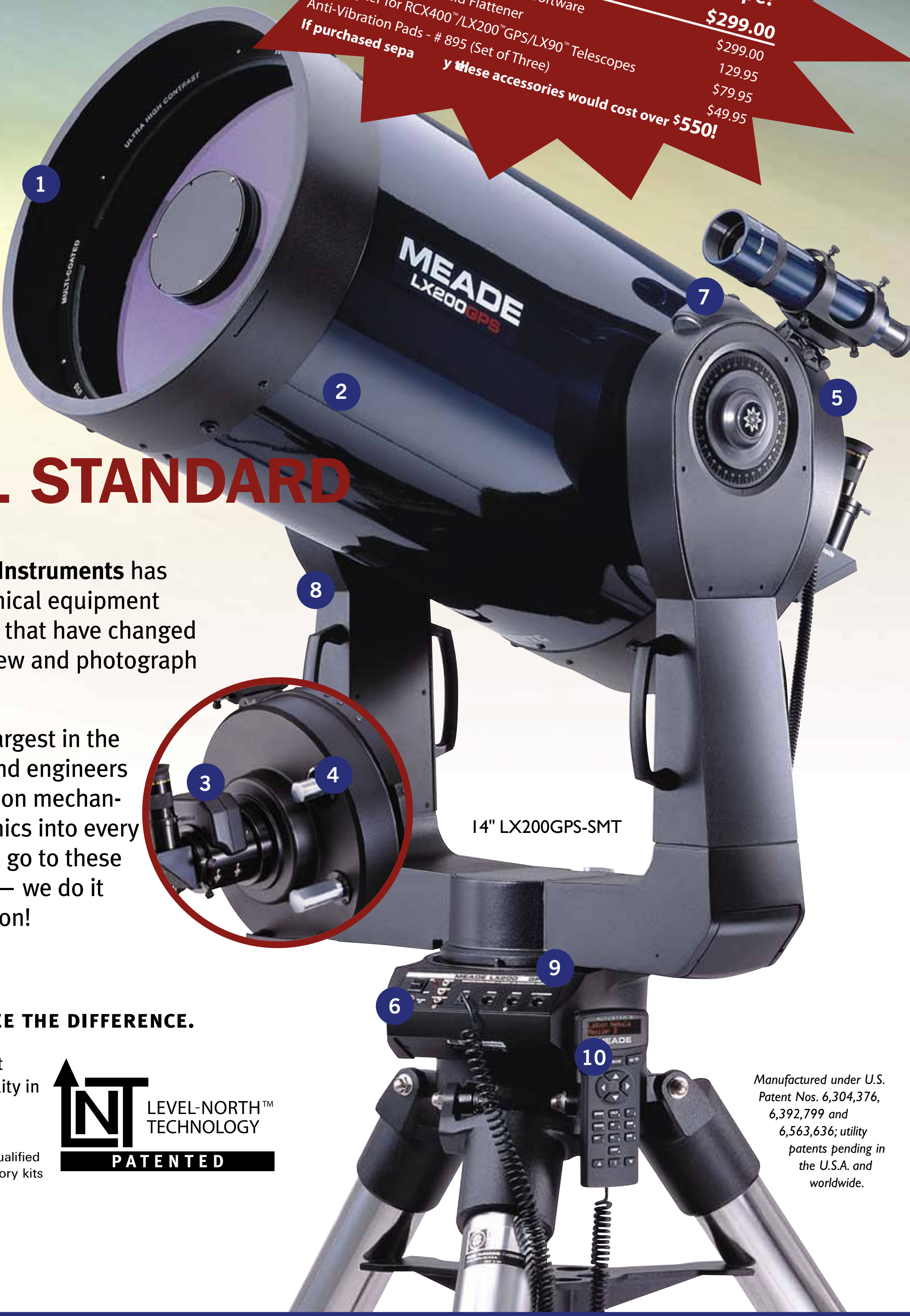

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6. Smart Drive™ provides permanent periodic error correction (PPEC) on both axes by learning n av Caging dror over the course of one or more training periods, thereby minimizing guiding corrections during long-exposure photographs. PPEC is available on both axes and functions in both polar and altazimuth modes.

MEADE EXCLUSIVE

7. Sony® GPS Receiver Sensor automatically inputs precise time, date, and geographical location to help quickly and precisely align the telescope.

MEADE EXCLUSIVE

8. LNT™ – Patented Level-North Technology allows you to quickly and precisely align your telescope by automatically leveling the telescope and determining True North. It then automatically slews the telescope to the first alignment star.

MEADE EXCLUSIVE

9. Smart Mount™ constantly refines pointing accuracy each time an object is centered and updated. Compatible with both equatorial and altazimuth mounts.

MEADE EXCLUSIVE

10. AutoStar® II controller features "Hot Keys" for quick access to a 145,000 celestial object database. AutoStar II can be updated with the latest software upgrades, guided tours and timely objects like comets free at meade.com.

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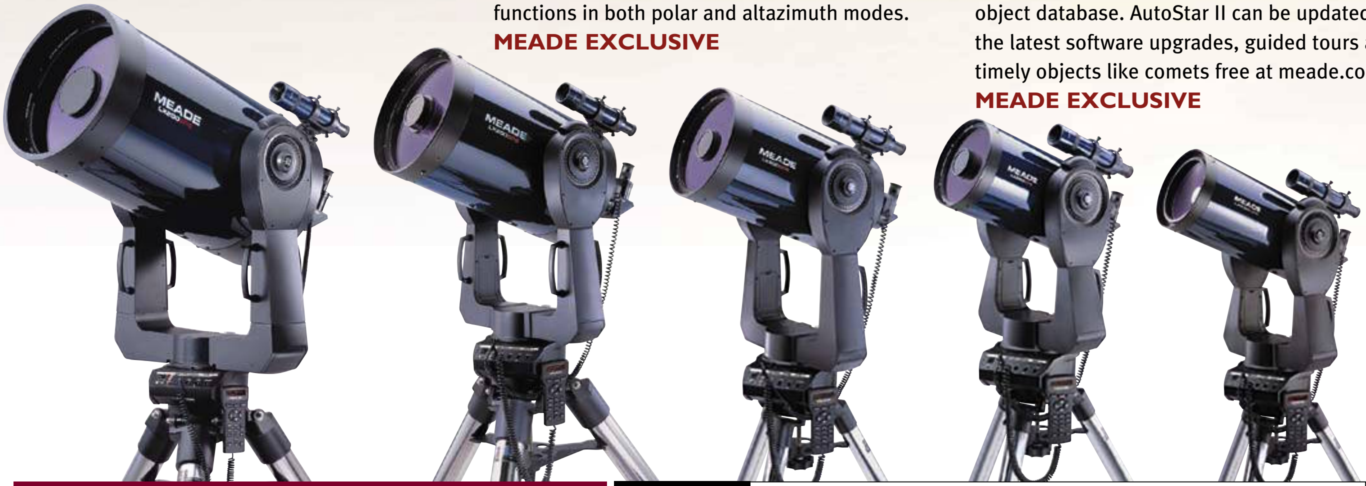

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OPTICAL DESIGN	SCHMIDT-CASSEGRAIN					MAKSUTOV-CASSEGRAIN
APERTURE	8"	10"	12"	14"	16"	7"
FOCAL RATIO	f/10	f/10	f/10	f/10	f/10	f/15
FOCAL LENGTH	2000MM	2500MM	3048MM	3556MM	4064MM	2670MM
U.S. PRICE (INCLUDES SHIPPING & HANDLING)	$2,299	$2,999	$3,799	$5,299	$10,499	$2,799
UHTC™(ULTRA-HIGH TRANSMISSION COATINGS)*	$175	$235	$295	$350	$495	$150
3/5 YEARS SKY ASSURANCE	$245/$560	$245/$560	$330/$850	$330/$850	$770/$1,139	$245/$560

* Option only at time of purchase

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Maksutov-Cassegrain

ETX-PREMIER EDITION™ TELESCOPES

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ETX-105PE Maksutov-Cassegrain (UHTC: add $75)	$899
ETX-125PE Maksutov-Cassegrain (UHTC: add $95)	$1,099

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ETX-70AT™

ETX-70 Refractor	$299

ETX ACCESSORY KITS

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* SERIES 4000™ 9.7MM SUPER PLÖSSL EYEPIECE
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* 45˚ ERECTING PRISM – #932

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You save $47!

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* AC ADAPTER – #541

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Schmidt-Newtonian – Refractor – Schmidt-Cassegrain

LXD75 TELESCOPES

6" Newtonian with Electronic Controller	$599
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LXD75 MOUNT + TRIPOD

Mount & Tripod (includes EC Dual-Axis Controller) (AutoStar #497: add $199)	$499

LXD75 OPTICAL TUBE ASSEMBLY

8" Schmidt-Newtonian (includes UHTC)	$799

LXD75 ACCESSORY KITS

LXD75 CELESTIAL OBSERVER'S KIT $199

* SERIES 4000 9.7MM SUPER PLÖSSL EYEPIECE
* SERIES 4000 15MM QX WIDE ANGLE EYEPIECh (70 AFOVe
* SERIES 4000 26MM QX WIDE ANGLE EYEPIECE (2") (70˚ AFOV)
* 2X BARLOW – #126

You save $66!

LXD75 DELUXE OBSERVER'S KIT $299

* SERIES 4000 9.7MM SUPER PLÖSSL EYEPIECE
* SERIES 4000 15MM QX WIDE ANGLE EYEPIECE (70˚ AFOV)
* SERIES 4000 26MM QX WIDE ANGLE EYEPIECE (2") (70˚ AFOV)
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* ANTI-VIBRATION PADS – #895 (SET OF THREE)
* AC ADAPTER – #547
* MOON FILTER – ND 96
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* VARIABLE PROJECTION CAMERA ADAPTER
* SERIES 5000™ 3X TELEXTENDER
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LX90™ TELESCOPES

Schmidt-Cassegrain

LX90 TELESCOPES

8" Schmidt-Cassegrain (UHTC: add $175)	$1,799
" Schmidt-Cassegrain (UHTC: add $2 5)	$2,299
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LX90 ACCESSORY KIT

LX90 ASTROPHOTOGRAPHER'S KIT $249

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Schmidt-Cassegrain – Maksutov-Cassegrain

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LX200GPS ACCESSORY KITS

LX200GPE ASTROPHOTOGRAPHER'S KIT $349

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* SERIES 4000 f/6.3 FOCAL REDUCER
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* ANTI-VIBRATION PADS – #895 (SET OF THREE)

You save $151!

LX200GPS DELUXE ASTROPHOTOGRAPHER'S KIT / $ 99

NEW

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* ANTI-VIBRATION PADS – #895 (SET OF THREE)
* VARIABLE PROJECTION CAMERA ADAPTER

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RCX400™ TELESCOPES

Advanced Ritchey-Chrétien Design

■ RCX400 TELESCOPES

NEW

10" RCX400-Advanced Ritchey-Chrétien (includes UHTC)	$5,149
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RCX400 ACCESSORY KITS

RCX400 ASTROPHOTOGRAPHER'S KIT $349

NEW

* SERIES 4000 f/6.3 FOCAL REDUCER
* SERIES 4000 PLÖSSL 9MM ILLUMINATED RETICLE (WITH CORD)
* VARIABLE PROJECTION CAMERA ADAPTER
* #644 FLIP MIRROR SYSTEM
* ANTI-VIBRATION PADS – #895 (SET OF THREE)

You save $151!

RCX400 DELUXE ASTROPHOTOGRAPHER'S KIT $499

NEW

* SERIES 4000 f/6.3 FOCAL REDUCER
* SERIES 5000 2X TELEXTENDER (1.25")
* #647 FLIP MIRROR SYSTEM
* SERIES 4000 PLÖSSL 9MM ILLUMINATED RETICLE (WITH CORD)
* ANTI-VIBRATION PADS – #895 (SET OF THREE)
* VARIABLE PROJECTION CAMERA ADAPTER

You save $260!

www.meade.com/series5000

SERIES 5000™ EYEPIECES

Ultra-Premium Eyepieces

■ 5 ELEMENT PLÖSSL SERIES 5000

NEW

Focal Length	Barrel Size	Apparent FOV	# of Elements	Price
5.5	1.25"	60˚	6	$89.00
9	1.25"	60˚	5	$89.00
14	1.25"	60˚	5	$89.00
20	1.25"	60˚	5	$89.00
26	1.25"	60˚	5	$99.00
32	2.00"	60˚	5	$149.00
40	2.00"	60˚	5	$199.00

■ SUPER WIDE ANGLE SERIES 5000

NEW

Focal Length	Barrel Size	Apparent FOV	# of Elements	Price
16	1.25"	68˚	6	$179.00
20	1.25"	68˚	6	$199.00
24	1.25"	68˚	6	$249.00
28	2.00"	68˚	6	$279.00
34	2.00"	68˚	6	$299.00
40	2.00"	68˚	6	$399.00

■ ULTRA WIDE ANGLE SERIES 5000

NEW

Focal Length	Barrel Size	Apparent FOV	# of Elements	Price
4.7	1.25"	82˚	7	$199.00
6.7	1.25"	82˚	7	$199.00
8.8	1.25"	82˚	7	$199.00
14	1.25"	82˚	7	$199.00
18	1.25"	82˚	6	$279.00
24	2.00"	82˚	6	$399.00
30	2.00"	82˚	6	$449.00

■ TELEXTENDERS SERIES 5000

NEW

Magnification	Barrel Size	# of Elements	Price
2x	1.25"	4	$159.00
3x	1.25"	4	$159.00
5x	1.25"	4	$159.00
2x	2.00"	4	$229.00

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LUMICON The World's Best Filters & Astronomical Accessories

Lumicon International offers the best and most extensive line of astronomical filters in the world. Filters for every imaginable visual and astrophotographic application, in many configurations and sizes. Filters for light polluted skies, planets, deep sky objects, galaxies, nebulae, planetary nebulae, comets, and solar prominences. All Deep Sky, UHC, OIII, H-Beta, and Comet Filters are individually tested and proudly inscribed with the percentage of light transmittance of their primary emission lines. Lumicon also offers a complete line of unique accessories, including the World Famous Easy Guider Series, Sky Vector Systems, Diagonals, Finderscopes, and Binocular Viewers. To ensure that Lumicon Products remain the World's Best, the strictest quality control standards are employed throughout the production process. All Lumicon Products are made to the highest standards available and come with a 100% Satisfaction Guarantee - Please Visit www.lumicon.com for details.

LUMICON DEEP SKY

DEEP SKY FILTERS The best light pollution filter on the market today. Blocks all high & low pressure mercury and sodium vapor lamp light, neon lights and airglow while transmitting the rest of the visible spectrum. Excellent for both visual and photographic applications. Visually, the Deep Sky Filter is most useful under light-polluted skies, from where it reveals faint objects like star clusters, galaxies, nebulae and comets by darkening the background of space. Photographically, the Deep Sky Filter enables deep space photos to be taken through city lights and blocks natural airglow at dark-sky sites, thus improving results in film and CCD astrophotography.

1.25″ – $99.95 • 1.25″ Questar – $99.95
2″ – $199.95 • Cassegrain Rear Cell – $199.95

LUMICON UHC

ULTRA HIGH CONTRAST FILTERS The ULTIMATE nebula filter. The original LUMICON Ultra High Contrast Filter is unbeatable for revealing nebulosity. This achievement in filter performance is attributed to exclusively designed coatings that isolate the two doubly ionized oxygen lines (496 and 501nm) and the H-beta line (486nm) emitted by planetary and most emission nebulae. The result is superb views of the Orion, Lagoon, Swan and other extended nebulae. Useful to great advantage under dark skies.

1.25″ – $99.95 • 1.25″ Questar – $99.95
2″ – $199.95 • Cassegrain Rear Cell – $199.95

LUMICON OIII

OXYGEN III FILTERS The legendary LUMICON OIII narrow bandpass filter isolates just the two doubly ionized oxygen lines (496 and 501nm lines) emitted by diffuse, planetary and extremely faint nebulae. Thus, these faint objects become much more visible against the blackened background of space. The LUMICON Oxygen III Filter produces near-photographic views of the Veil, Ring, Dumbbell and Orion nebula, among many other objects. Performs best under both light-polluted and dark skies. You will be amazed at what the OIII filter allows you to see!

1.25″ – $99.95 • 1.25″ Questar – $99.95
2″ – $199.95 • Cassegrain Rear Cell – $199.95

LUMICON H-BETA

HYDROGEN-BETA FILTERS The Horsehead Nebula filter. The LUMICON H-Beta Filter isolates only the hydrogen-beta line of the spectrum (486nm) in a narrow pass-band just 9 nm wide. The result is extreme contrast between the black background of space and the delicate Hydrogen - Beta emission of extended nebulae. Now you can view extremely faint, special objects such as the Horsehead, Cocoon and California Nebulae. In many cases, the LUMICON H-Beta Filter is the ONLY way to view these objects. A transparent sky, a 8″ or larger telescope, and the LUMICON H-Beta Filter, will tremendously aid in viewing those "notch in the belt" objects.

1.25″ – $99.95 • 1.25″ Questar – $99.95
2″ – $199.95 • Cassegrain Rear Cell – $199.95

LUMICON SWAN BAND

COMET FILTERS The LUMICON Comet Filter, a narrow bandpass system (25nm), isolates the 501nm OIII line and both Cyanogen lines at 511nm and 514nm. The high contrast gain of the filter reveals the delicate ionized tail of gaseous comets, allowing you to see their full extent. The Comet Filter also helps you to better distinguish gaseous comets from dusty comets which normally show little contrast gain.

Howard Brewington, famed comet discoverer, says: "I discovered Comet Aarseth-Brewington, 1989a1, using the LUMICON Comet Filter. The filter doubled the contrast, making the comet very easy to spot." Why make comet-hunting harder than it needs to be?

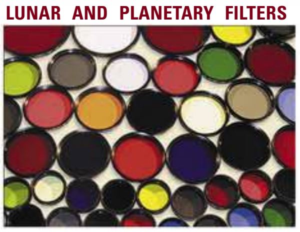
1.25″ – $99.95 • 1.25″ Questar – $99.95
2″ – $199.95 • Cassegrain Rear Cell – $199.95

NIGHT-SKY HYDROGEN-ALPHA FILTERS Not intended for solar observing, the LUMICON Night-Sky H-Alpha Filter is a powerful photographic aid in overcoming light pollution during deep-sky photography. It will greatly reduce light pollution, making it ideal for photography of faint emission nebulae. Exposures may be increased up to 10 times without diminishing the black background in your photograph, thus, achieving strikingly improved results in black & white film and CCD astrophotography. Both filter surfaces have high light transmittance coatings for maximum performance.

2″ – $69.95 • 58mm – $79.95 • 77mm – $89.95 • 82mm – $99.95

MINUS VIOLET FILTERS The LUMICON Minus Violet Filter greatly improves photographs taken through lens systems, producing pinpoint star images. It is especially recommended for all telephoto lenses. The Minus Violet filter passes the maximum amount of visible light, including the full blue, green, yellow and red portions of the spectrum. It absorbs violet and ultraviolet light below 420nm, thus eliminating blue halos around bright stars in color photography. In B&W photography it eliminates bloated and swollen star images caused by violet and ultraviolet light, which telephoto lenses cannot focus perfectly, due to chromatic aberration. This filter is unsurpassed in photographic performance.

2″ – $69.95 • 58mm – $79.95 • 72mm – 89.95



LUNAR AND PLANETARY FILTERS LUMICON Lunar and Planetary filters are made from renowned Schott and Hoya optical glass. Each filter is individually precision ground and highly polished with ultra-high light transmittance coatings on both sides for ultimate contrast on lunar and planetary detail. Double stacking filters may also improve lunar imaging. Optimized for both visual and photographic applications. For a complete list of lunar and planetary filters and applications, please visit www.lumicon.com. 1.25″ – $19.95 • 2″ – $29.95

LUMICON Rotating

POLARIZING FILTERS LUMICON Polarizing Filters are manufactured from optically flat Hoya polarized glass. Performs best at cutting all glare and increases contrast on bright celestial objects such as the moon at full illumination, and can be double-stacked with other LUMICON filters for use on bright planets. They are also useful for daylight observation of land, sea and nature. In addition to polarizing the light, they reduce its intensity by a factor of about 3.

Also available in rotating polarized cell designs for variable levels of light transmittance to any value between 5% and 30%.

Single Polarizer 1.25″ – $29.95 • 2″ – $39.95
Variable Polarizer 1.25″ – $39.95 • 2″ – $49.95

• NEW • NEW • NEW •

80MM SUPER FINDER SYSTEM The highest quality finder system on the market today, the newly redesigned LUMICON 80mm Super Finder features exceptionally sharp optics, high contrast views and easy to use functionality. The LUMICON 80mm Super Finder is designed to switch conveniently from straight through to right angle in seconds with supplied extension adapter. Includes a front barrel focuser for fast and precise focusing. In addition, the LUMICON 80mm Super Finder includes a correct image right angle diagonal for hassle free pointing in any direction.

The LUMICON 80mm Super Finder also doubles as a high quality rich field refractor, yielding superb views of the moon, planets, star clusters, bright galaxies as well as daytime images. Use it with the optional Image Visor and reduce glare while increasing contrast and resolution on lunar and terrestrial views.

Objective Lens: Fully Multi-Coated 80mm Achromatic Lens; Focal length: 300mm; Includes a Quality 25mm Kellner Crosshair Eyepiece; Super Finder System Weight: 2.7 lbs. Body color available in Black or White.

80mm Super Finder System – **$299.95**
80mm Super Finder Body (Body Only) – **$219.95**
Image Visor – **$24.95**
2X Fully Coated Barlow Lens – **$39.95**

UNIVERSAL DOVETAIL FINDERSCOPE BRACKETS The LUMICON Universal Dovetail Finderscope Bracket will securely hold your finderscope to your telescope. The dovetail design permits fast removal and reinstallation of your finderscope while maintaining the alignment to your telescope. Mounts on most telescope tubes, with adjustments for other tube designs. Made from solid aircraft aluminum.

50mm Universal Dovetail Finderscope Bracket – **$49.95**
80mm Universal Dovetail Finderscope Bracket – **$59.95**
Universal Dovetail Bracket Spare Base – **$14.95**
Universal Dovetail Bracket Tripod Mounting Base **$19.95**

MULTIPLE FILTER SELECTORS LUMICON Multiple Filter Selectors allow you to switch back and forth between filters without having to thread and unthread them from your eyepieces or diagonal. The nose-piece also has threads, so one filter, such as a neutral density or polarizing filter, can be "stacked" with the others. Leaving one of the slots open lets you compare views with and without your LUMICON filters. Made from solid aircraft aluminum.

1.25″ Multiple Filter Selector Features: Fits Standard 1.25″ Filters; 5 Filter Positions; 6oz Light Weight Construction; 5/ ″ Low Profile Design; Includes 1.25″ Eyepiece Adapter and T-Thread Adapter. Price – **$129.95**

NEW 2″ Multiple Filter Selector Features: Fits Standard 2″ Filters; 4 Filter Positions; Light Baffles for Astrophotography; 8oz Light Weight Construction; 5/8″ Low Profile Design; Includes 2″ Eyepiece Adapter and Male Cassegrain Rear Cell Adapter. *Filters sold separately.*

Introductory Price: **$169.95**

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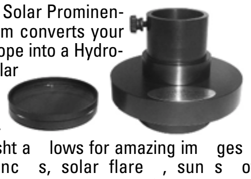
LUMICON
Blow Off Duster
LUMICON MC

ADVANCED CLEANING KIT The very best cleaning kit ever offered. The LUMICON Advanced Cleaning Kit has everything you need to clean even the most delicate lenses and mirrors. Safe to use on all optical surfaces. Includes LUMICON Lens Cleaning Spray, LUMICON Multi Coated Optics Cleaning Fluid, LUMICON Lens Cleaning Tissue, Ultra Brush Dust Remover, Air Blower Blush, 100% Cotton Swabs, LUMICON Micro-Fiber Cleaning Cloth, "Blow Off" Compressed Air and a Hard Carrying Case.

Introductory Price: **$39.95**

SOLAR PROMINENCE FILTER SYSTEM



The LUMICON Solar Prominence Filter System converts your existing telescope into a Hydrogen – Alpha solar telescope. Viewing the sun in Hydrogen – Alpha lisht a lows for amazing im ges f solar prominenc s, solar flare , sun s ots, bright filame ts nd other surface features. Simply use a standard camera T-Ring and SLR camera for full photographic capabi1ity. $Safely observe and photograph the sun at high and low powers directly through your own telescope.

The LUMICON Solar Prominence Filter System includes three components: 1. The Energy Rejecti – Prefilter; blocks all harmful radiation before it enters your telescope. 2. The Off-Axis Mask; stops down your objective and holds the Energy Rejection Prefilter. 3. The SPF Body; extremely narrow-band (1.5 Angstrom) Hydrogen-Alpha filter, providing high contrast imaging of solar features. This portion of the filter slideC into a 2" focuser or diagonal. Includes a T-Thread camera adapter and a 1.25" eyepiece adapter.

Solar Prominence Filter System for 7" / 8" Cassegrain – $779.95 • Meade 10" SCT – $789.95 • Celestron 11" SCT – $799.95 • Meade 12" SCT – $809.95 • Celestron 14" SCT – $819.95 • Meade 14" SC – $819.95• Meade 16" SCT – $899.95

Solar Prominence Filter Kit available for telescopes not listed here. The Off-Axis Mask is not included and can be fabricated by customer. Price - $699.95

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2" Enhanced Diagonal - $189.95

umiBr te Mirror Diago als

With greater than 98 percent light reflectivity, 1/10 wave precision polished optics and individually performed double pass collimation tests, the LUMICON u i-B gt Diagpnalf maximize the perfor a ce P your telescope for ultimate contrast and resolution one can get from a star diagonal. The exceptional Dielectric Coating provides for a more durable and longer lasting surface. Additionally, objects appear much brighter, with truer color. Includes standard filter threads for trouble-free changing of eyepieces and accessories while using filters. Made from solid aircraft aluminum.

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Specifications: Clear Aperture: 22mm; Focus Travel: 20mm; 1.25" Barrel, Threaded for Filters; Magnification: 1X; Overall Length: 120mm; Weight: 23 oz.

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N wtonian Refractor Easy Gui ers

The LUMICON Newtonian/Refractor Easy Guider allow2 off-ax s gpiding directly through the main telescope, preventing differential flexure between your telescope and guide scope, which can ruin your astro h$ os. The low profile design installs in seconds into standard 1.25" and " focusers. Accommodates standard filters and Aam a T-Rings.

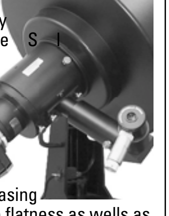
Newtonian/Refractor Easy Guider 1.25" – $189.95
2" – $189.9

Cassegrain Easy Guiders

The LUMICON Cassegrain Easy Guider allows off-axis guiding with you 5" – 9.25" cassegrain telescope. The included multi-coated 50mm focal reducing lens reduces the f-ratio from f/10 to f/6.5 or f/5, providing a wider field of view, increased edge flatness nd rtEr exposure times. The faster f-ratio combined with the ease of inding and guiding on bright stars, minimizes guiding error, making for successful astrophotos. Accommodates standard 2" filters and camera T-R n s.

Cassegrain Easy Guid C for Celestron 5"l – $249.95 • 7" - 9.25" – $249.95

Giant Easy Guiders



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Giant Easy Guider Meade 10" - 16" SCT – $399.95 • Celestron 11" - 14" SCT – $399.95

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Incredible feats

"Titan Touchdown" (April 2005) led me to realize the Cassini-Huygens mission's accomplishments. A spacecraft still traveling through our solar system captured amazing images of Saturn and its moons and jettisoned a companion that landed on Titan. ☾ We witnessed the Columbia disaster, several setbacks with NASA's space shuttle program, Genesis' crash into the desert floor, the Hubble Space Telescope's looming death, and the European Space Agency's failed Beagle 2. But think of Cassini-Huygens, the enduring twin rovers on the martian surface, and Stardust returning to Earth with cometary samples.

ESA/NASA/UNIVERSITY OF ARIZONA

SATURN'S MOON TITAN, is home for Huygens — the probe that provided a never-before-seen view of the satellite before dying on its surface 3 hours later.

We've experienced recent unfathomable successes in space. Think of what we'll see after learning from our mistakes.
— **JERRY COLLINS,** PHOENIX

"Titan touchdown" demonstrated the scientific worth of the Cassini-Huygens mission. Sadly, the snapshots from Titan's surface give further evidence of what an aesthetic disappointment much of the solar system has turned out to be. Pictures from the surfaces of our Moon, Mars, and now Titan show vistas that look like the same gravel pit, with different color schemes for each site. The knowledge gained is priceless, but for me, the landscapes leave something to be desired.
— **JULIUS WROBLEWSKI,** VANCOUVER, BRITISH COLUMBIA

Just for beginners

Binoculars are great tools for those getting started in astronomy, as Phil Harrington pointed out in "Binoculars under $100" (April 2005).

I can attest, thanks to a herniated disk caused by lugging my 16-inch scope to a dark-sky site, binoculars can be a medical must-have for savvy astronomers.
— **RICHARD WHITE,** PLANO, TEXAS

Coyne of the realm

The interview with Father George Coyne (March 2005) was a welcome treat.

In it, the issue of "perceived conflicts between science and religion" arose.

I suggest these conflicts between Judeo-Christian literalists and proponents of the scientific method only are minor. Their differences stem from their different orders of proof: For literalists, it is faith; for scientists, it is verifiable evidence.

To study the Bible as a history textbook or science journal is to miss the point. To argue the validity of faith is a waste of time.
— **HENRY STUART,** McKINLEYVILLE, CALIFORNIA

Interesting detail

I was delighted to view the 2 B.C. coin depicted in "Striking ancient skies" (March 2005). On the reverse side, Earth is represented by a globe. The Roman coin creators were not the only Europeans who knew our planet is a revolving globe. Language tells us how many others viewed Earth in centuries past. Think of our synonym for Earth: world. This is a close relative of the Dutch word "wereld," old Norse "verold," and old Swedish "varalde." The first part of this word, whether "ver," "var," or "vor," is seen in "vertex," "vortex," and the English verb "veer," meaning "to turn." The second element is identical to Basque "alde," or "zone." The world is the "turning zone," not the Sun, nor the sky.

German "welt," or "world," is similar. This is related to Italian "volta" or Spanish "vuelta," both meaning "to turn"; and old Norse "velta," meaning "to roll over."

How did these people of ancient civilizations know Earth revolves? Their descendants certainly abandoned the knowledge and lost the meaning behind "world," "welt," or close relatives.
— **FELICITY CROW,** STROUD, ENGLAND

We welcome your comments. Send letters to Astronomy *Letters, P. O. Box 1612, Waukesha, WI 53187; e-mail to letters@astronomy.com. Please include your name, city, state, and country. Letters may be edited for space and clarity.*

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Expect a surprise

Astronomy enters our brains in two flavors — news that surprises us and news that doesn't. When we learn of another extrasolar planet, or of NASA's next Mars mission, it's nice, but we're hardly bowled over. Face it, most of us aren't accountants or bureaucrats — we're restless, we want to be amazed. We love the unexpected.

Surprise can be a tricky subject. A case in point is this headline in the April 4, 1979 *Atlanta Journal*: "Sneak Attack by Soviets Not Foreseen."

Former *Scientific American* columnist Martin Gardner tells a wonderful childhood story about how his older brother, like most siblings, would harass him. On April Fool's Day his brother said he would fool Martin like he'd never been fooled before. All night, Martin could barely sleep, waiting for the prank, but in the morning Martin's brother announced he had fooled him simply by doing nothing.

Gardner recalls being tormented by this. He had expected to be fooled, had not been fooled, and therefore had been fooled. On the other hand, because he was thus fooled and had gotten what he expected, in what sense had he really been fooled?

Truly amazing astronomy announcements fool even the experts. They're discoveries no one expected. Would finding microscopic life beneath the martian surface be a bombshell surprise? Not really. Finding that the Sun is actually hollow and filled with steamed broccoli — that would be a surprise.

Any science surprises we might try to predict would automatically not qualify. So our best guide to the future is a look back through history, recalling where we've had our collective minds blown.

We can't say a round Earth realization and the Sun-as-center-of-the-solar-system (heliocentric) revelation were true surprises because some people had long suspected these things. The first real bombshells came through Galileo's telescope in the 17th century: Nobody had dreamed that unattached rings could surround a planet! An even bigger shock occurred in 1781 with William Herschel's Uranus discovery.

It seems strange to us now that a green hydrogen ball with all the intrigue of a chili dog should have astonished the world, but it did. That's because there always had been five planets in the sky. It was the way things were, period. Nobody imagined for a moment that there might be more planets, invisible ones.

IT SEEMS STRANGE to us now that a green hydrogen ball with all the intrigue of a chili dog should have astonished the world, but it did.

Next true surprise? Well, germs, but we're talking astronomy here, so we'd have to go to Einstein's revelations that space bends and time isn't constant. In 1924, Edwin Hubble found that all those pinwheel nebulae lie outside the Milky Way. Suddenly, the universe was a thousand times bigger. It had been suspected, but still, a universe that extends for billions of light-years? Aren't we still trying to get a handle on that one?

In 1933, Fritz Zwicky found there's far more dark matter than visible stuff. Most of the universe is made of strange material that cannot be seen. Whoa!

How about the discovery of neutron stars in the 1960s? The public never had conceived of matter packed so tightly. All the steel contained in a giant cruise ship squashed down to the size of an apple seed. That's the actual density of the Crab pulsar, emerging from behind the Sun this month: a perfect sphere of indestructible material 12 miles across. And it still astounds: Neutrons and protons have that same density. Imagine, the identical packing job lurks in every atom in your body. It's right here, not just far away. A century ago, nobody expected such a thing.

The big surprise of the 1980s was that the universe isn't a random sprinkling of galaxy clusters; instead they form filaments among giant voids. No theorist had foreseen that on the largest scales the cosmos would be structured like a sponge.

Just a few years ago came the big head-spinner that the universe's expansion is speeding up. It caught everyone off guard. A universe slowing down was gospel. Speeding up, blowing itself apart at an ever-faster clip? If true — and it appears so — then the universe must be dominated by some kind of anti-gravity force. We call it "dark energy" and we still have no idea what the heck it is.

See the pattern? A true surprise has to change a basic established belief, or alter our view of the universe. At the least, the discovery must be a new phenomenon coming out of left field. In the past century these have happened about once a decade, so the next probably will arrive soon.

We'll be surprised if it doesn't.

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{ GLENN CHAPLE'S OBSERVING BASICS }

BY GLENN CHAPLE

Solar observing

Last month, I described two safe ways to make telescopic Sun observations — indirect viewing by solar projection and direct viewing with an aperture filter ("Good Sun behavior," page 16). This month we look at two technological innovations guaranteed to make your backyard explorations of our nearest star even more exciting and rewarding.

If the mere mention of technology puts a knot in your stomach, you're not alone. Over the years, I've developed a love-hate attitude toward technology. I love being able to word-process this column on a computer and instantly e-mail it to *Astronomy*. I hate that, by pressing the wrong key, I might send the article to a laundromat in Romania.

You'll be pleased to know that the innovations I'm about to describe are reliable, user-friendly, and relatively inexpensive. And they'll definitely add pizzazz to your sungazing.

Inexpensive imaging eyepieces

Imaging technology, where a small CCD camera substituted for the eyepiece relays the image to a TV monitor, has been available to professional astronomers for decades. In recent years, several companies, including Meade and Orion, have marketed low-cost imaging eyepieces for amateur use. I purchased one, and quickly discovered its value for solar astronomy.

I place an aperture solar filter at the front end of a 60mm refracting telescope (remember, you don't need a large-aperture telescope to view the Sun). The imaging eyepiece is secured in the focuser and connected by a cable to the video port of a small TV/VCR combo. Once the scope is aimed properly, the Sun's image appears on the screen. By pressing the "Record" button on the TV/VCR, I can videotape the Sun's activity. A collection of these video clips gives me a nice record of sunspot activity.

Low-cost hydrogen-alpha filters

The methods of solar observation I've mentioned so far provide what's known as a white-light image of the Sun. A white-light solar image, which shows sunspots on the solar surface (photosphere), is interesting. A hydrogen-alpha (Hα) image, which reveals prominences and activity in the Sun's chromosphere, is jaw-dropping.

CLAIRE UNDERWOOD

CLAIRE UNDERWOOD

A LITTLE INNOVATION **can go a long way. Chaple hooks up his telescope to a VCR to record solar observations to share with his class. He used this technique to record a few minutes of the 2004 Venus transit.**

The Hα filter is another innovation that once was available only to the professional astronomer or the amateur who didn't mind shelling out a king's ransom to purchase one. Last year, Coronado Technology Group unveiled its Personal Solar Telescope (PST) — an Hα filter/telescope combination that costs $499. The PST has taken the astronomical world by storm (see "Coronado's Personal Solar Telescope," January 2005).

In addition to being affordable, the PST is easy to operate — so easy, in fact, that its "manual" is a one-page flyer. In minutes, I mount my PST on a camera tripod and gaze in awe at a living, breathing star. The Sun's red disk (an Hα filter lets in a thin sliver of sunlight in the red portion of the spectrum) seems alive with activity — around the solar disk's edge, prominences arc into space.

A fascinating sight

Whether viewed by traditional means or with high-tech gear, our nearest star is a fascinating telescopic sight, and sungazing is a wonderful way to extend your astronomical pursuits to the daytime.

All right, so maybe the articles I e-mail to this magazine don't wind up in a Romanian laundromat. A few months ago, however, I learned an e-mail I sent to a fellow amateur astronomer wound up in his junk mail file. I'm conscientious about answering all correspondence sent my way, so if you don't receive a reply to an e-mail you sent me, try again. Contact me at *gchaple@hotmail.com*.

Next month: We revisit the Ring Nebula, then "scoot to Scutum." Clear skies.

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DSLR II shown on a Canon 10D*

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{ PHIL HARRINGTON'S BINOCULAR UNIVERSE }

BY PHIL HARRINGTON

A tail's tale

The constellation Scorpius the Scorpion is a rare breed. Why? Because Scorpius is a constellation that actually looks like what it's supposed to represent. No trying to force a centaur aiming an arrow out of a star pattern that looks more like a teapot — like neighboring Sagittarius. The stars of **Scorpius** actually trace the outline of a scorpion — complete with two stars for its poisonous stinger at the end of a hook-shaped body.

The bright orange star **Antares**, marking the Scorpion's heart, also attracts our attention. Even though it lies about 600 light-years away, Antares is the 15th brightest star in the night sky.

Antares puts on a grand show through binoculars, but a clear view to the south is needed to truly appreciate it. Although Antares is red, its low altitude often causes it to put on quite a colorful light show, flickering among red, orange, yellow, white, and even blue and green. This distorting effect, caused by the turbulent layers of our planet's atmosphere, can be dazzling.

If you look carefully just to the west of Antares (to the right, if you are located north of Earth's equator, or to the left if to the south), you should see a fuzzy smudge of light among the surrounding field of stars. That's **M4**, a globular cluster containing perhaps 100,000 stars. Antares and M4 appear close in the sky by circumstance. In reality, M4 is about 12 times farther away, lying 7,200 light-years from us. Although far away, it's one of the closest globulars.

Next, proceed southward along the Scorpion's crooked body. Stop partway at two wide double stars, **Mu** (μ) and **Zeta** (ζ) **Scorpii**. Although both are just chance line-of-sight pairings, the area between them is dazzling through binoculars.

ONLINE EXTRA Learn more about this article's objects, spectral types, and nearby star clusters by visiting us on the web at www.astronomy.com/toc

Be sure to pause at open cluster **NGC 6231**, which lies just north of (above) Zeta. Some 120 searing blue and blue-white stars are crammed inside this tight cluster. They look faint through binoculars because we are seeing them from 5,900 light-years away. But if we could magically reduce that distance to that of the Pleiades cluster (380 light-years), the brightest stars in NGC 6231 would outshine Sirius in our sky.

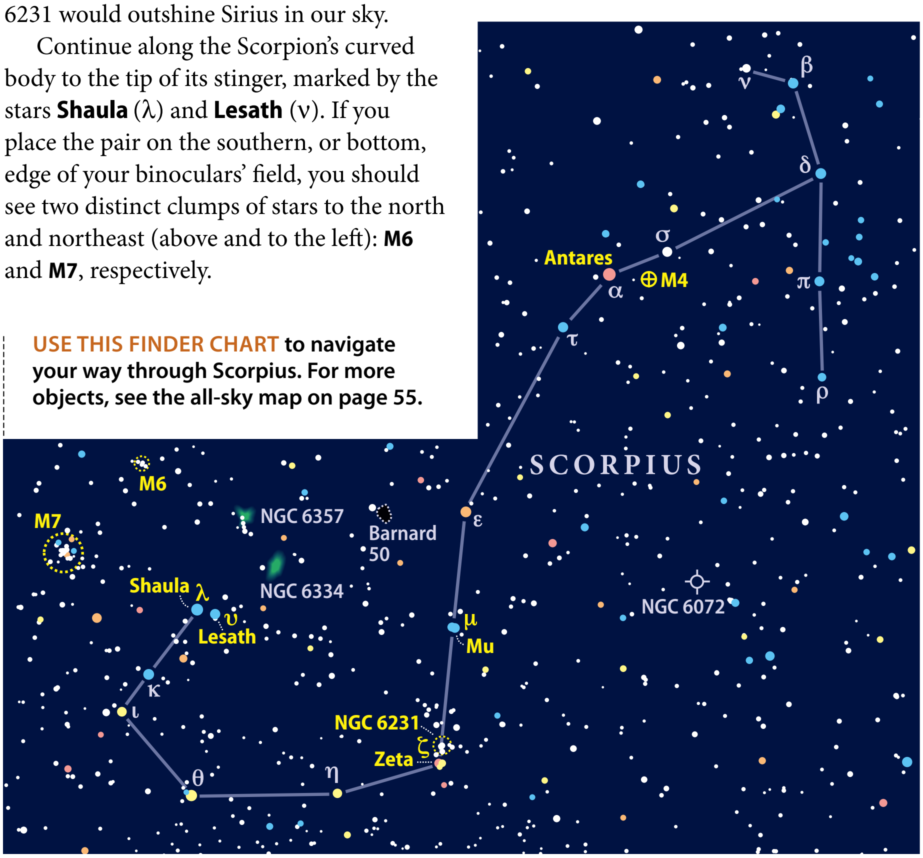
Continue along the Scorpion's curved body to the tip of its stinger, marked by the stars **Shaula** (λ) and **Lesath** (ν). If you place the pair on the southern, or bottom, edge of your binoculars' field, you should see two distinct clumps of stars to the north and northeast (above and to the left): **M6** and **M7**, respectively.

The brightest stars in M6 seem to form a rectangle, although more inventive eyes can imagine a butterfly's outline among the stars. Look for two wings outstretched from the butterfly's centered body. The butterfly appears to be headed southeast.

M7 is larger and brighter than M6, and so should be more obvious. Even in the smallest binoculars, M7 will burst into a striking assortment of stars covering an area larger than the Full Moon. Several of its 80 stars show subtle hues of yellow and blue, with the brightest a yellow beacon lying close to the group's center.

Visit *Astronomy.com* for more heavenly targets within Scorpius.

Next time out, we'll go on a binocular tour of our galaxy's center. Meanwhile, remember: Two eyes are better than one!



USE THIS FINDER CHART to navigate your way through Scorpius. For more objects, see the all-sky map on page 55.

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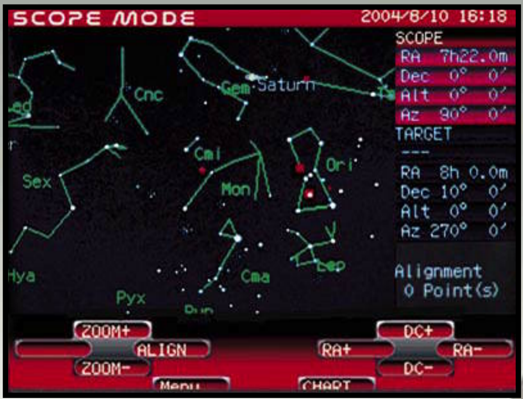
SCOPE MODE 2004/8/10 16:18

SCOPE
RA 7h22.0m
Dec 0° 0'
Alt 0° 0'
Az 90° 0'

TARGET

RA 8h 0.0m
Dec 10° 0'
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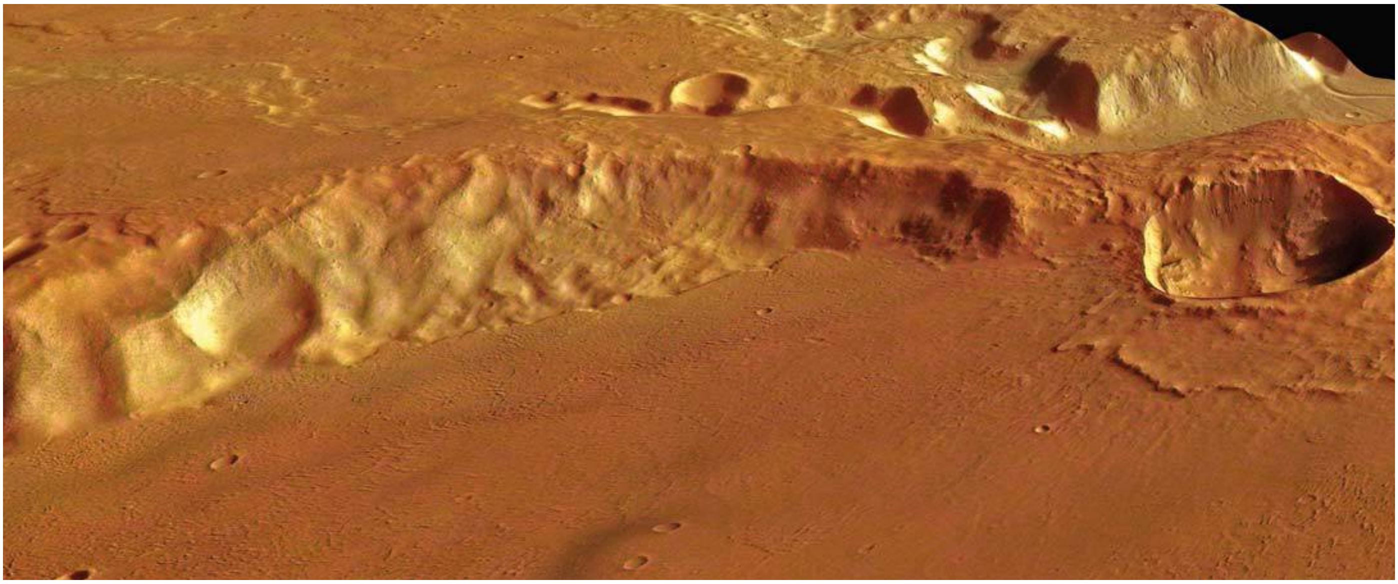
MOVING SWIFTLY. NASA's Swift gamma-ray satellite measured its first two distances to gamma-ray bursts March 18 and 19. The March 18 burst was 9.2 billion light-years away, the other 11.6 billion light-years.

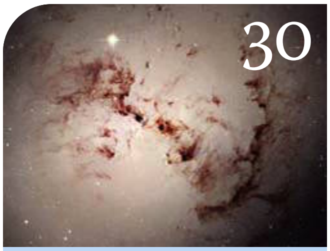
news 07

A super-snooper Mars spacecraft, Spitzer finds dust-cloaked "invisible" galaxies, an alien asteroid belt, and disputes over first images of extrasolar planets.



ESA/FU BERLIN, G. NEUKUM

DICHOTOMY. **The highland/lowland boundary on Mars spans an elevation change of 2 to 3 miles (3 to 5 kilometers). This view looks southwest over one part of the boundary near 5° south and 213° east. The Medusae Fossae formation (foreground) is smooth, gently rolling material that in places has been eroded by the wind into ridges and grooves. The crater at right is shown in the image below.**



26 Do elliptical galaxies have dark matter after all?

27 New Milky Way satellite

28 Andromeda Galaxy much larger than suspected

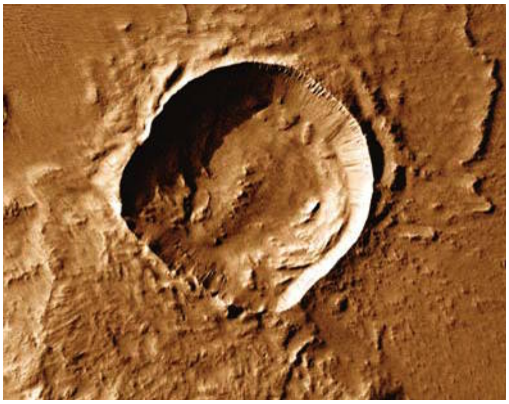
30 Dusty residue of a galactic smash-up

Medusae Fossae: the view from Mars Express

Mars shows two faces: one high and cratered, the other low and smooth. What caused this dichotomy in the martian crust has been long debated. Giant impacts, arrested plate tectonics, crustal composition differences, and more have all been suggested. The answer still eludes scientists' grasp.

The Medusae Fossae formation straddles the boundary where the northern lowlands meet the southern highlands in the region between Tharsis and Elysium, two centers of volcanic activity. Scientists think the formation was deposited by volcanic ash falls or debris flows.

These images were taken by Mars Express' High-Resolution Stereo Camera in Amazonis Sulci. — **ROBERT BURNHAM**



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SPLAT. **This crater, 6 miles (9 km) across, has lobed ejecta, showing the ground contained water or ice.**

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GO SLOW. **Nebulae at the edges of elliptical galaxy M105 orbit slowly, suggesting the galaxy has little dark matter. Computer simulations point to a different solution, however.**

Missing dark matter found in ellipticals?

Astrophysicists think they've found evidence for dark matter halos in elliptical galaxies. The new finding contradicts 2003 studies and it supports the view that lots of dark matter provided the gravitational clout to start galaxies forming. It also suggests dark matter still surrounds elliptical galaxies.

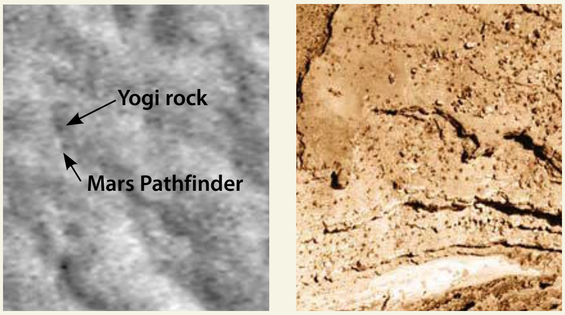
Dark matter's pull explains why gas clouds on the edge of spiral galaxies orbit as fast as gas and stars closer to the center. In 2003, two astronomers clocked the speeds of planetary nebulae in five elliptical galaxies. They found velocities dropped with distance from the galaxies' centers, which suggested ellipticals contain little or no dark matter.

Now, astrophysicist Avishai Dekel (Hebrew University, Jerusalem) thinks he's found evidence for dark matter in ellipticals.

Dekel and his colleagues simulated collisions between 10 pairs of spiral galaxies wrapped in dark-matter halos. As expected, the simulated mergers produced elliptical galaxies within huge dark-matter cocoons.

The group found slow-moving stars on highly elongated orbits litter the outskirts of newborn ellipticals. Dekel says these exiled stars become the slow-moving planetary nebulae seen before. The stars' elongated orbits, Dekel writes, "naturally explain the low velocities despite the massive presence of dark matter." — **ROBERT ADLER**

Super-snooper goes to Mars



NASA/UNIVERSITY OF ARIZONA

LOOK CLOSELY. **The HiRISE camera on the Mars Reconnaissance Orbiter is sharper than the best previous orbital camera. At left, a MOC view of the Mars Pathfinder landing site; at right, a simulated HiRISE shot in the Grand Canyon. Both images show equal areas.**

The Golden Age of Mars exploration will continue in August with the launch of the Mars Reconnaissance Orbiter (MRO).

MRO is the latest probe in a series that has achieved a new level of Mars operations. Where missions once were sporadic and brief, they are now frequent and long-lived.

When MRO arrives at Mars in March 2006, it will find several older probes still active in orbit. Also, there may be one or two mechanical Methuselahs still roving the ground.

MRO should return up to 40 times more data to Earth than any previous Mars spacecraft, and over more powerful data links. It will be the largest probe ever to orbit Mars (some Russian probes came close). It will be in the lowest Mars orbit ever to sharpen its view of ground features and, scientists hope, water deposits underground.

On-site Mars Rover assays of surface minerals have shown measurements from orbit are often misinterpreted. MRO's three cameras will map the surface in high detail, noting geological features as small as volleyballs.

Perhaps someday MRO will detect some mysteriously missing spacecraft, if they haven't been covered with dust. But it's not hardware the probe is seeking, it's water — in distinctive landforms, in unique minerals, or in pure form.

The Italian Space Agency built MRO's shallow radar sounding instrument (SHARAD), designed to probe for evidence of underground layers of ice, rock, and perhaps water.

Unlike the MARSIS radar on Europe's Mars Express, SHARAD concentrates on the shallow subsurface and at much higher resolution. If aquifers lie deep, perhaps melted by planetary heat, MRO won't detect them. But where any water can interact with surface minerals, the data should be magnificent.

Radar signals lose strength on both the outgoing and returning legs of their path; signals weaken by the fourth power of the distance. This makes it critically important for radar to be as low as possible. MRO's orbit therefore will just skim the thin upper atmosphere (160 miles or 255 km up), and the probe will enter the atmosphere when the mission ends.

From this low vantage point, some cameras will zoom in for close-ups, while others will take wide-angle surveys of atmospheric activity, including variations in ozone distribution.

By monitoring changes in water vapor at different altitudes, MRO could even find plumes of water vapor in the atmosphere that come from underground sources — if there are any.

Another camera looks outward, in the best traditions of Mars-based astronomy. NASA's Jet Propulsion Laboratory has built an optical navigation camera that will use the observed positions of Phobos and Deimos to demonstrate precision navigation for future missions. What it finds on the surface will help scientists select landing sites for these missions.

— **JAMES OBERG**

HOMES, SWEET HOMES. Astronomers using computer models have found as many as half the 134 known extrasolar planet systems have habitable zones where earthlike planets could orbit long enough for life to appear.

NYU, B. WILLMAN/IAA, D. MARTINEZ-DELGADO/ISAAC NEWTON TELESCOPE

ALMOST MISSED IT. A newfound dwarf spheroidal galaxy (dimmest stars) is so faint that astronomers nearly didn't discover it. The brighter stars lie closer to Earth and belong to the Milky Way Galaxy.

New Milky Way satellite

A diffuse collection of stars southwest of the Big Dipper's bowl is a small galaxy orbiting our own, say astronomers. The newfound galaxy, at 10h35m, 51°55' (2000.0), lies roughly 330,000 light-years away — only twice as far as the Large Magellanic Cloud, the Milky Way's brightest satellite galaxy.

Beth Willman (New York University) and her colleagues, searching data from the Sloan Digital Sky Survey, noticed an excess of stars in the constellation Ursa Major. They then observed the region with the 82-inch (2.5-meter) Isaac Newton Telescope in the Canary Islands.

In a paper submitted to *The Astrophysical Journal Letters*, the team reports the Ursa Major galaxy is a dwarf spheroidal — a small gas-poor galaxy whose few stars lie widely separated from one another. Half the galaxy's light comes from a region 1,600 light-years across, typical of dwarf spheroidals.

Willman's team says the new galaxy resembles the Sextans dwarf spheroidal, another Milky Way satellite. Both dwarf galaxies are ancient and have few metals — elements heavier than hydrogen and helium.

However, the new galaxy is much less luminous than the Sextans dwarf, having only about a tenth as many stars. Willman and her colleagues estimate it emits only 1/350,000 as much light as the Milky Way. This makes it, for now, the least luminous galaxy ever seen. In fact, some individual *stars* in the Milky Way, such as Deneb in Cygnus, give off more light than all the stars in the newly found Ursa Major dwarf galaxy put together. — **KEN CROSWELL**

N. TANVIR, M. IRWIN, AND A. HUXOR

NOT A GLOBULAR. A new type of giant star cluster belongs to the Andromeda Galaxy, M31.

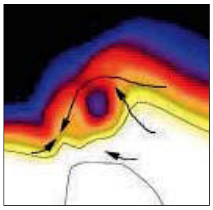
M31 has "extended" giant star clusters

Neighbor galaxy M31 has at least seven unusual star clusters, says a team of astronomers. The clusters contain 100,000 stars or more, like globular clusters, but are much larger — hundreds of light-years across — and more diffuse.

The team calls them "extended clusters." Nothing similar lies in the Milky Way.

Team member Avon Huxor says how they formed is a mystery. "The clusters are ancient," she says, "possibly among the first objects to form in the universe." — **R. B.**

Making chondrules with shock waves



INDIANA UNIVERSITY

DO THE WAVE. When shock waves hit dust, simulations show it fuses into chondrules.

As the solar system formed, shock waves surfed the protoplanetary disk from Jupiter's orbit, striking dust grains hard enough to fuse them, say scientists using computer simulations. The blows made chondrules, millimeter-size beads that form the bulk of rocky meteorites.

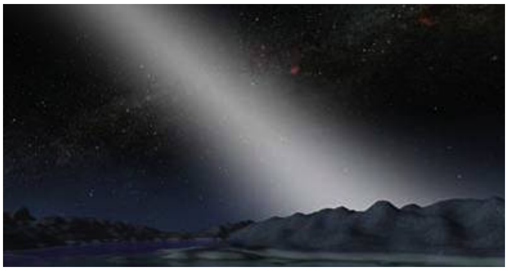
Recent work (see News, May 2005) suggested gamma-ray bursts could spark lightning to melt the grains.

Now, simulations made by two research groups show that in the disk massive clumps of gas formed in a gravitationally unstable zone near Jupiter's orbit.

The clumps created huge waves that spiraled across the protoplanetary disk, raising shock fronts like breakers hitting a beach.

When dust grains and shock waves collided, the dust fused into chondrules. — **R. A.**

Spitzer spots an alien asteroid belt



NASA/JPL-CALTECH

WARM GLOW. Dense dust in HD 69830's asteroid belt shines brightly in this artist's view.

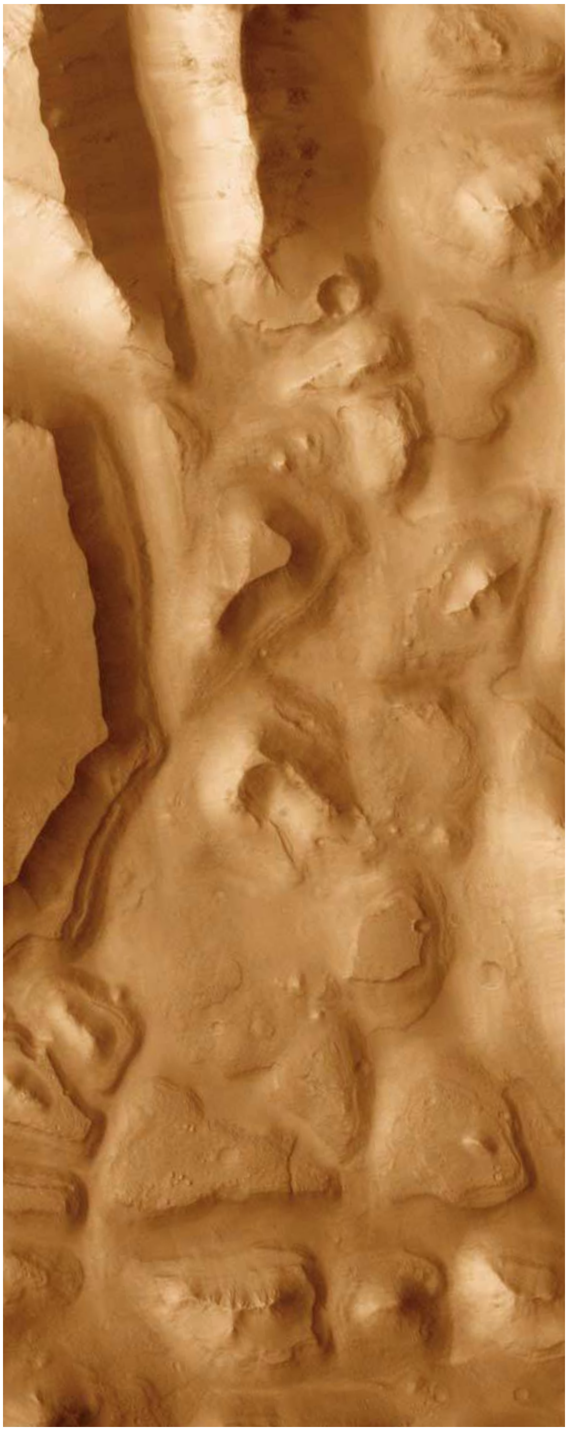
The Spitzer Space Telescope has seen a disk of warm dust probably generated by collisions in a rocky asteroid belt orbiting a sunlike star, says a team of astronomers led by Charles Beichman (Caltech).

The asteroid belt surrounding HD 69830, 41 light-years away, has 25 times more material than the Sun's does.

With HD 69830, the rocky belt lies inside a distance equal to Venus' orbit (0.72 astronomical unit). Ours lies between the orbits of Mars (1.5 AU) and Jupiter (5.2 AU). The team notes an unseen planet might be shepherding the alien asteroid belt, much as Jupiter corrals our own.

Two other asteroid belts are known, but they orbit younger, more massive stars. — **R. B.**

LOOKS BIG. Studies by astronomers say the next generation of ground-based optical telescopes will be 50 to 100 meters (165 to 330 feet) across. See *www-astro.physics.ox.ac.uk/~imh/ELT/Glossy/ELT-Brochure.pdf.*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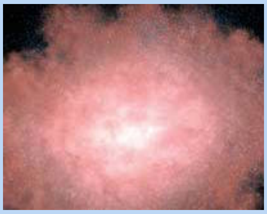
Collapse in Eos Chasma

TABLELANDS. Mesas and buttes stand in jumbled array in Mars' Eos Chasma at the east end of Valles Marineris. This kind of terrain results when water or melting ice bursts out of the ground, which then collapses. The Mars Odyssey THEMIS visual image, sunlit from the left, is about 17 miles (27 km) across.


NASA/JPL-CALTECH, T. PYLE

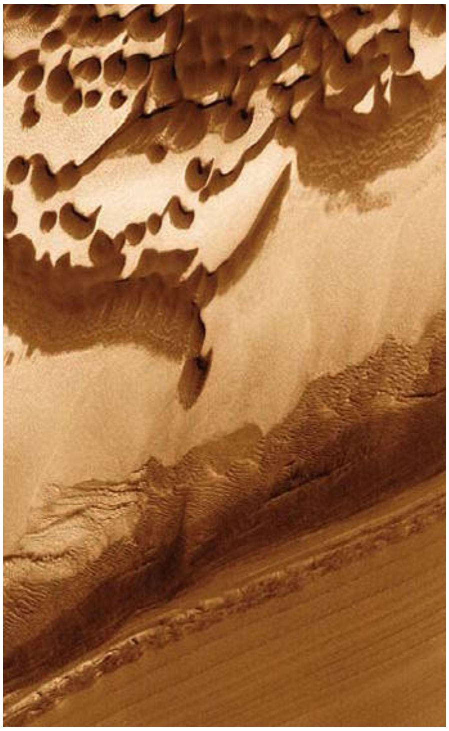
DUST SHROUD. An artist's view shows a galaxy hidden in dust, as it might appear to infrared eyes.

Spitzer sees dusty, "invisible" galaxies

Astronomers with the Spitzer Space Telescope have found 31 galaxies that are big and bright but so dusty they're visible only in infrared.

The galaxies lie 11 billion light-years away and date from 3 billion years after the Big Bang. Each is as bright as 10 trillion Suns, or a thousand Milky Ways.

In *The Astrophysical Journal Letters* (March 3), a team led by James Houck (Cornell University) reports evidence of silicate dust in the spectra of 17 of the 31 galaxies. — **R. B.**


NASA/JPL/MSSS/IMAGE R22-01171

POLAR DEBRIS. Dark dunes (top) crawl across the floor of Chasma Boreale, a large valley cutting into Mars' northern polar cap. The dune sand may be volcanic debris that weathered out of the layered polar cap, seen at bottom. Sunlit from the lower left, this image from Mars Global Surveyor spans 1.9 miles (3 km).

M31 is much bigger than it looks

A huge disk of stars surrounds the Andromeda Galaxy (M31), say astronomers. The newfound disk spans at least 260,000 light-years, almost twice the size of the bright disk seen in photos, and it emits nearly 10 percent of the galaxy's light. M31 may have stripped these stars from smaller galaxies that strayed too close.

Lying just 2.5 million light-years away, the Andromeda Galaxy is the nearest giant spiral to our own.

Rodrigo Ibata (Strasbourg Observatory, France) and colleagues used the Keck Telescope in Hawaii to study regions near M31. They were astonished to find stars speeding around the galaxy far beyond the edge of its main disk.

NOAO/NSF/AURA, B. SCHOENING AND V. HARVEY

BIG, REALLY BIG. The Andromeda Galaxy has a disk of stars around it that nearly doubles its size.

The newfound disk is faint but blends smoothly into the bright one. If our eyes could see the entire disk, M31's long axis would span more than 11 Full Moons. — **K. C.**

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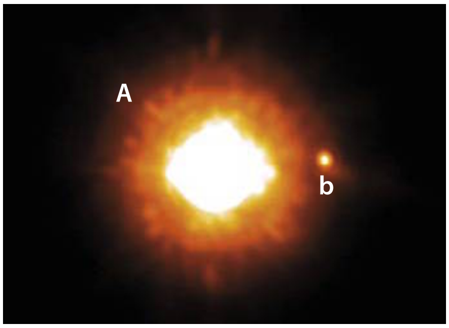
BYE-BYE MOON. Astronomers thought Kuiper Belt object Sedna spun so leisurely (20 days) it must have a moon to brake its spin. But no moon was found. New work shows Sedna spins every 10 hours, and no moon is necessary.



ESO

FIRST LIGHT? Nearby brown dwarf GQ Lupi (A) has a planet (b), according to one team of astronomers. Others say the secondary object is too massive for a bona fide planet.

Exoworlds: fights over first light

Which astronomer team captured the first light (or, to be picky, radiation) from an extrasolar planet? Answer: it all depends.

A team led by Ralph Neuhäuser (University of Jena, Germany) says they have taken the first direct image of an extrasolar planet.

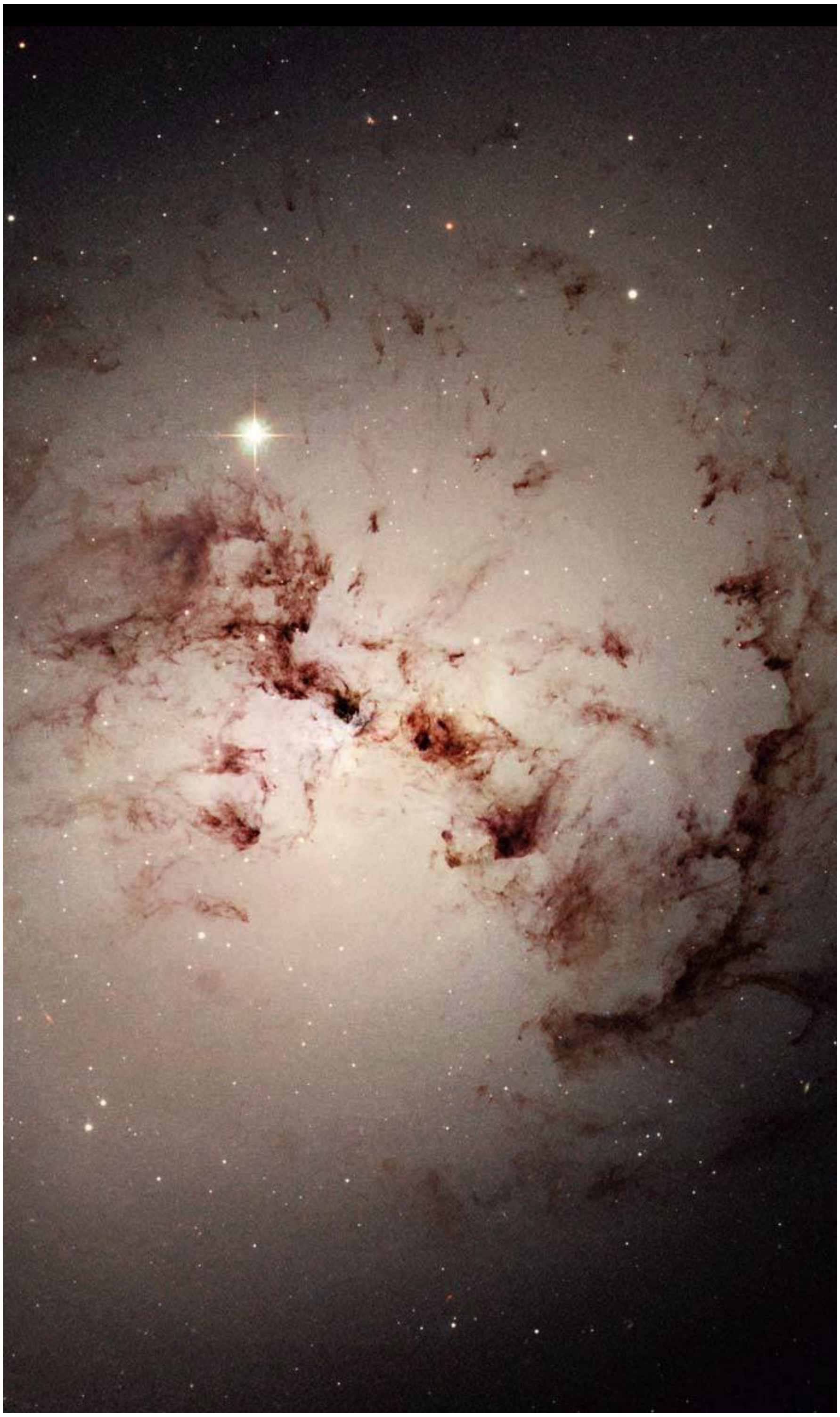
This object belongs to the young star GQ Lupi, which shines 250 times brighter. The object lies roughly 100 astronomical units from GQ and its infrared spectrum suggests a temperature between 1,600 and 2,500 kelvins, or 2,900° to 4,500° F.

The object's mass remains unknown, however, and theoretical models indicate a range of 3 to 42 Jupiters, spanning the line between planets and brown dwarf stars.

Earlier (see News, April 2005), astronomers led by Glenn Schneider (University of Arizona) released an image of a possible planet of the brown dwarf 2M1207, but it was unconfirmed. Then in late March, two independent teams reported detecting radiation from two known "hot Jupiters" using the Spitzer Space Telescope.

The team of David Charbonneau (Center for Astrophysics) measured the infrared light from the planet TrES-1 using eclipses with its star. Drake Deming (NASA Goddard Space Flight Center) led a team that also used a stellar eclipse to measure the heat of planet HD 209458b.

Who won? Hard to say. In any case, astronomers stand on the edge of a new and exciting era in exoplanet study. — **R. B.**



NASA/ESA/HUBBLE HERITAGE TEAM

Dusty residue of a galactic smash-up

SHARPENING THE LOOK. Astronomers using the Advanced Camera for Surveys on the Hubble Space Telescope imaged galaxy NGC 1316, also known as radio source Fornax A. The dust clouds, known earlier, appear in newly sharpened detail. NGC 1316 is the outcome of two gas-rich spiral galaxies that collided.

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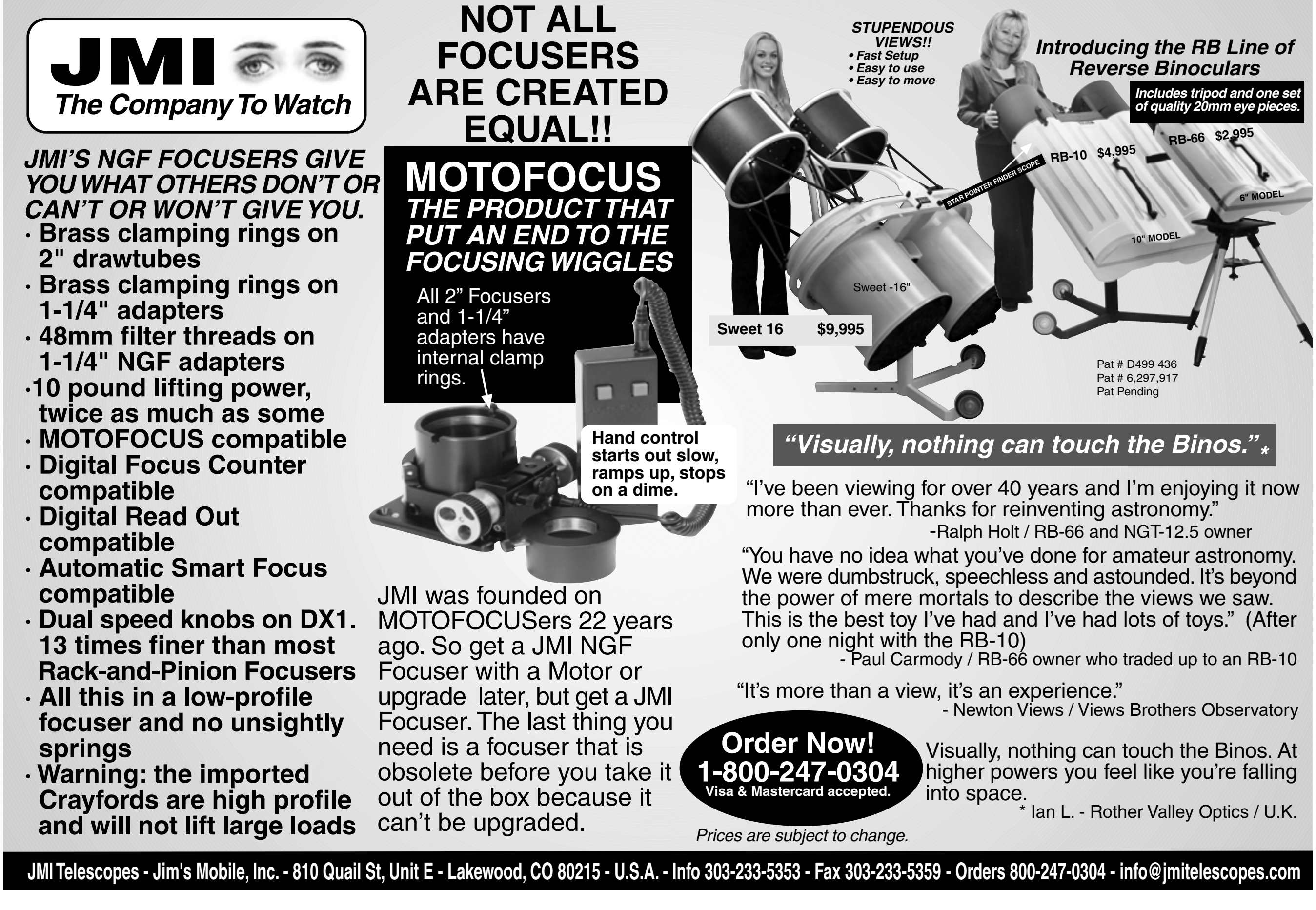

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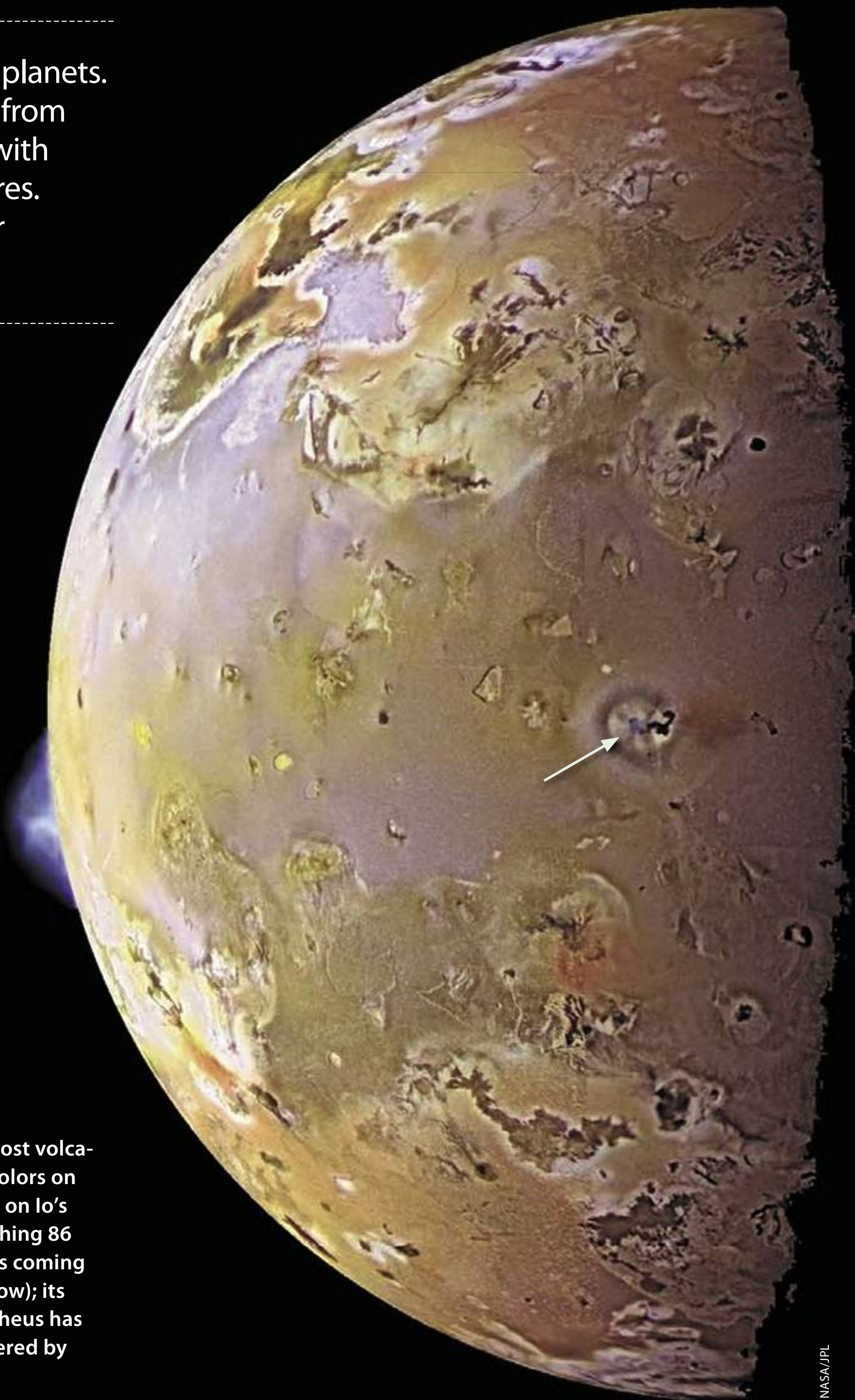
{ PLANETARY SCIENCE }

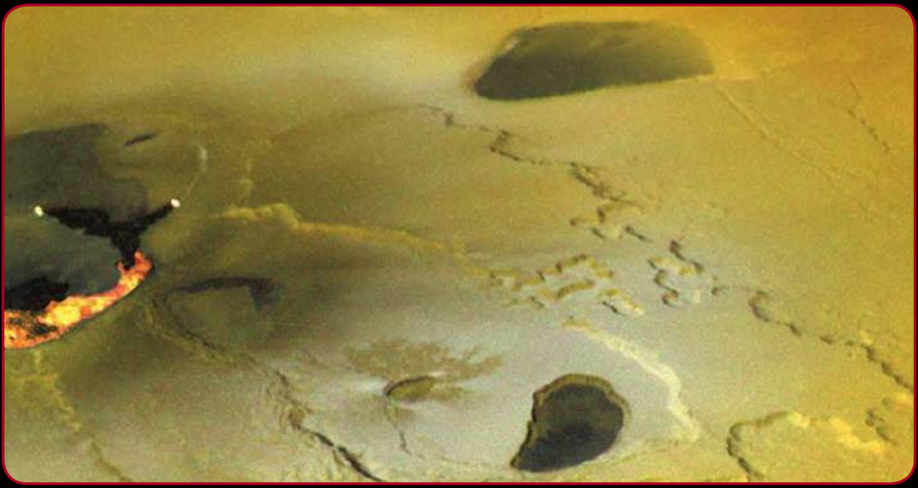
Mysterious microworlds

Everyone knows the Sun has nine planets. But it also has 141 moons varying from icy fragments to complex worlds with volcanoes, oceans, and atmospheres. Take a tour of the *rest* of the solar system. /// BY JACQUELINE GARGET



A WORLD OF FIRE, Jupiter's moon Io is the most volcanically active body in the solar system. The colors on the surface come from sulfur. The blue cloud on Io's limb is from an eruption at Pillan Patera reaching 86 miles (140 kilometers) high. Another plume is coming straight at the camera from Prometheus (arrow); its shadow is reddish. Scientists believe Prometheus has been continuously active since it was discovered by Voyager 1 in 1979.

NASA/JPL



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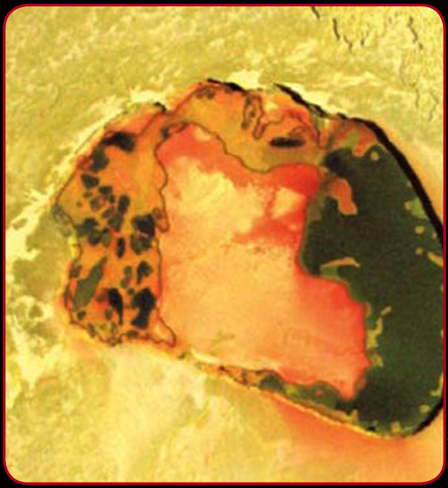
LAVA GLOWS ORANGE **at Tvashtar Catena, a chain of volcanic craters — calderas — on Io. The erupting lava lake seen at left extends more than 40 miles (60 km). Earlier eruptions and tectonic collapses built the slab-and-mesa topography. Older, but still relatively recent flows appear black and unstained by yellow sulfur.**



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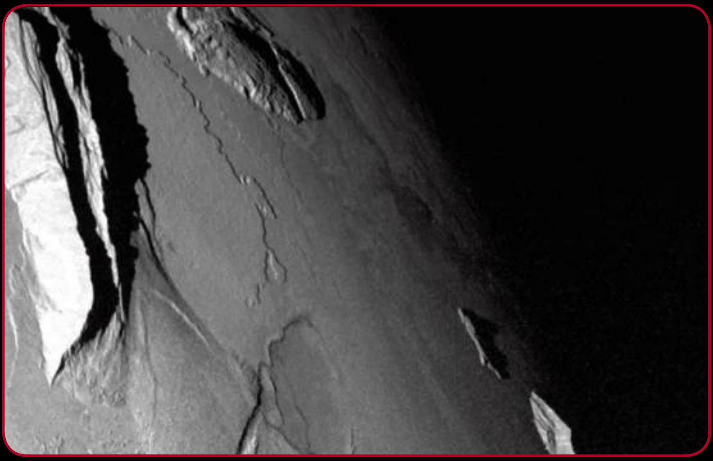
A VOLCANIC CRATER, **Tupan Patera displays colors produced by sulfur. The caldera is about 50 miles across (75 km) and has cliffs 3,000 feet (900 meters) high.**



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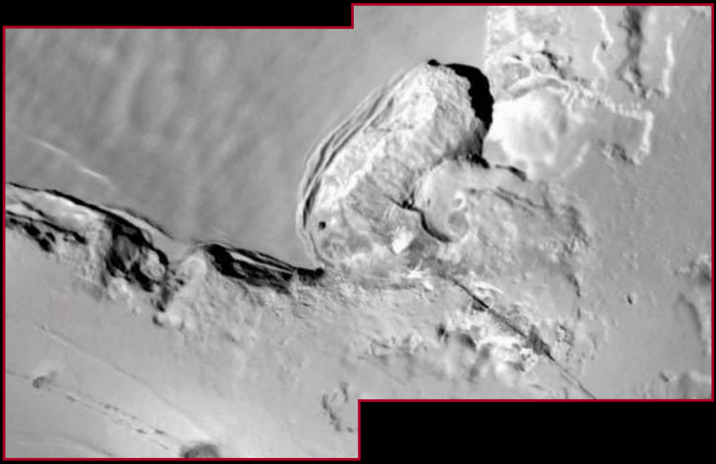
CAUGHT AT SUNSET, **mountains on Io rise above the plains. Mongibello Mons (at left) reaches an altitude of 23,000 feet (7 km). Scientists think Io's peaks are crustal blocks raised by activity along faults.**



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A COLLAPSING CLIFF **at Telagonus Mensa on Io has tumbled rubble about 2.5 miles (4 km) from the foot of the cliff, which is about 3,300 to 7,000 feet high (1 to 2 km).**

When Italian astronomer Galileo Galilei discovered the four largest moons of Jupiter in 1610, they amazed the astronomical world. The discovery also lent support to the Copernican universe, then struggling for acceptance. Discoveries of new moons by today's astronomers don't carry as much significance. But big or small, complex or fragmentary, moons offer a horde of alien worlds to explore.

Defining a moon is straightforward — it's a natural body in orbit around a planet. But wrapped in that simple definition lies a wide range of diversity.

Think of Earth's Moon, and a large, unchanging mass of rock covered in craters comes to mind. Our Moon has changed little in appearance during the last 3.5 billion years. But other moons differ greatly. Some have atmospheres, erupting volcanos, even oceans — they are living, evolving worlds.

Moons range in size from Jupiter's enormous Ganymede, larger than our Moon by half and bigger even than the planet Mercury, down to tiny, elusive shards of rock following bizarre orbits in the aftermath of collisions.

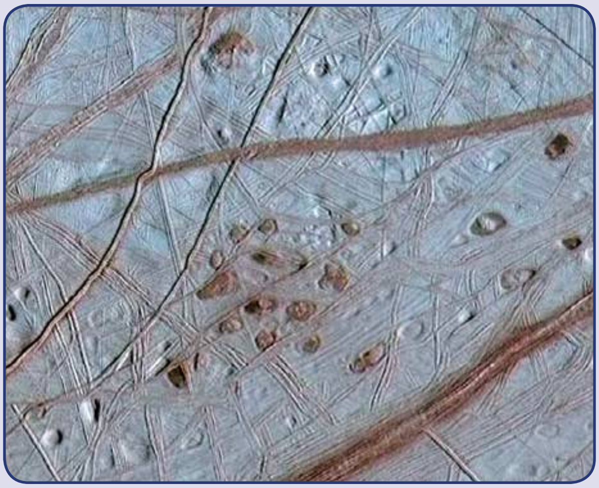
If we include everything right down to dust-size particles, then the solar system's moon-count effectively stands at infinity — but without defining how big a moon needs to be, planetary scientists stop short of that extreme. Jupiter currently leads the pack with 63 known moons, while Saturn's total of 34 trails a distant second.

In all, the population stands at 141. But current moon-counts for the outer planets are hardly final. Programs to search for small, distant moons turn up new discoveries frequently — see "Vagabond moons," *Astronomy*, May 2005.

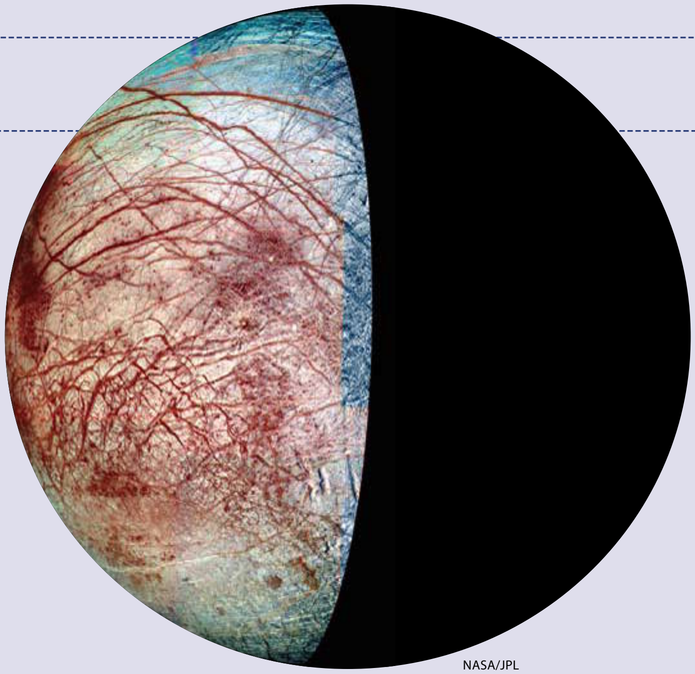
Space-age eyes

Only recently could astronomers build detailed pictures of the moons. The best ground-based telescopes provide no more than blurred views, and even the Hubble Space Telescope doesn't get much closer to the moons than a telescope on the ground.

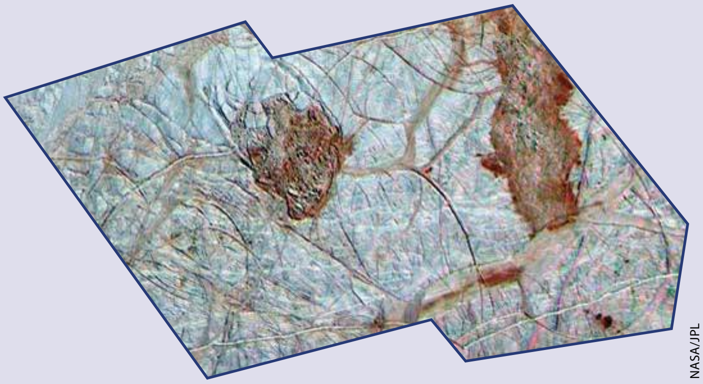
ICY VOLCANISM


NASA/JPL

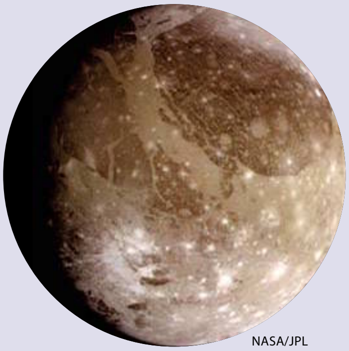
SPOTS AND PITS mark Europa's ice surface. Each spot or pit is about 6 miles (10 km) across. Scientists think warmer ice slowly works up through the shell, bringing impurities with it, like a kind of moon-wide lava lamp.


NASA/JPL

RED CRACKS AND BLUE ICE scar the surface of Jupiter's moon Europa in this false-color image, enhanced to bring out the differences between clean ice (blue) and ice stained with sulfate salts (red). Europa has an ice shell of unknown thickness over a global ocean of salty water that may be 60 miles (100 km) deep. Europa is a world dominated by icy tectonics.


NASA/JPL

THERA AND THRACE are two dark, enigmatic regions on Europa, perhaps created by melt-throughs of warm water or ice from below. Thera (left) measures about 40 by 50 miles (70 by 85 km).


NASA/JPL

JUPITER'S GANYMEDE is the largest moon in the solar system, outsizing even the planet Mercury. Dark areas are older and contain more rock in the surface ice. The light-brown regions feature younger, cleaner ice, and geologically recent impact craters show white.

But visits by spacecraft reveal details of these complex and diverse worlds from close-up. The flyby missions of Voyagers 1 and 2, launched in 1977, discovered new moons on their journeys past Jupiter, Saturn, Uranus, and Neptune. The two probes also revealed for the first time each satellite's surface, opening the door for planetary scientists to study these bodies' histories.

Building on the extraordinary success of the Voyager missions, the Galileo spacecraft spent more than 7 years orbiting Jupiter. From arrival in December 1995 to the plunge into Jupiter that ended the mission in September 2003, the spacecraft sent back a wealth of information (including about 14,000 images) on the planet, its four Galilean satellites, and numerous smaller jovian moons.

Most recently, the Cassini spacecraft, having arrived at Saturn in July 2004, is currently providing close-up images of Saturn, its rings, and its moons. The picture show should continue until at least 2008.

Going to extremes

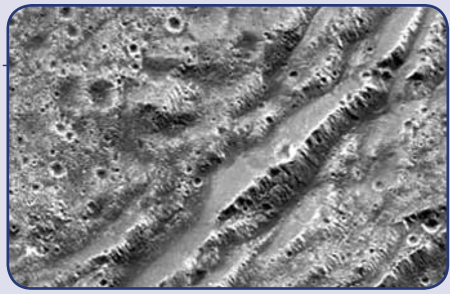
Spacecraft investigations of solar-system moons have revealed an incredible variety of characteristics. Temperatures range from one extreme to another. For example, Jupiter's fiery moon Io is the most volcanically active body known, erupting lava at temperatures up to 3,600° Fahrenheit (2,000 kelvins) — hotter than any lava on Earth.

In contrast, Neptune's moon Triton has the coldest measured surface of any natural body in the solar system: –391° F (38 K). This is only 68° F warmer than absolute zero, the temperature at which all molecular motion stops.

Voyager 2 revealed fascinating details about Triton, previously thought by scientists to be a dead world. Despite the cold, Triton has volcanos, although they differ greatly from volcanos we are familiar with on Earth — or Io, for that matter.

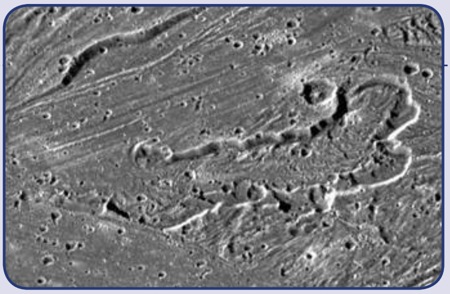
Triton's volcanos appear powered by solar heat trapped within the nitrogen ice on its

Jacqueline Garget *is a science writer and editor based in the United Kingdom.*



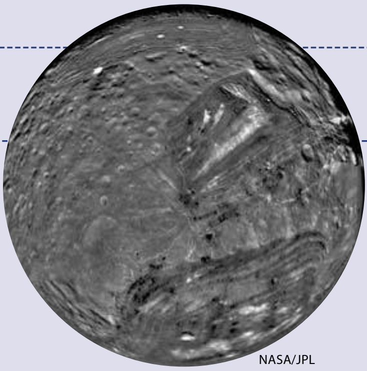
NASA/JPL/BROWN UNIVERSITY

STAIR STEPS created by faults make ridges and valleys in Ganymede's Nicholson Regio, a piece of ancient terrain. The view spans about 10 miles (16 km) wide. Scientists think the faulting occurred when the icy terrain was pulled apart.



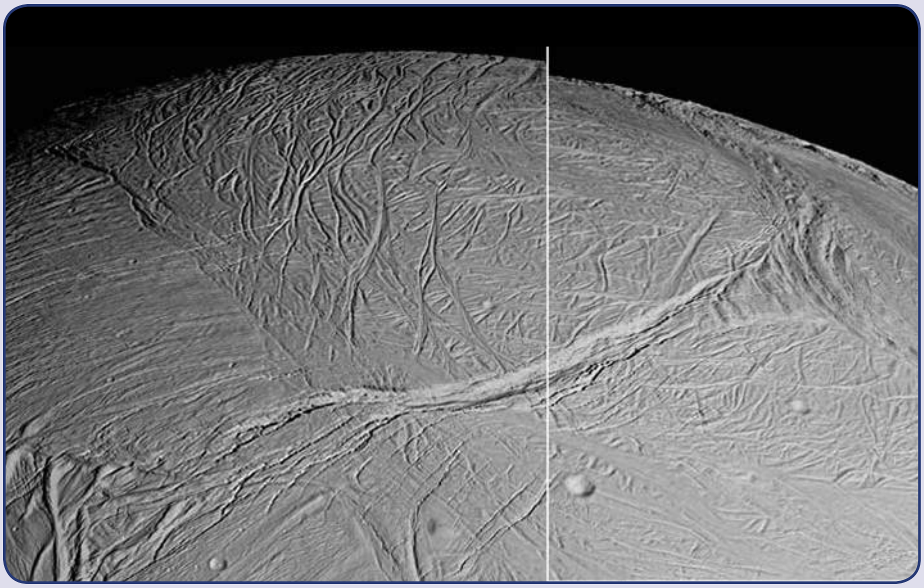
NASA/JPL

A FALSE "CALDERA" appears where an icy volcanic flow carved the ridged terrain in Sippar Sulcus on Ganymede. The depression is about 35 miles (55 km) long and about 12 miles (20 km) wide.



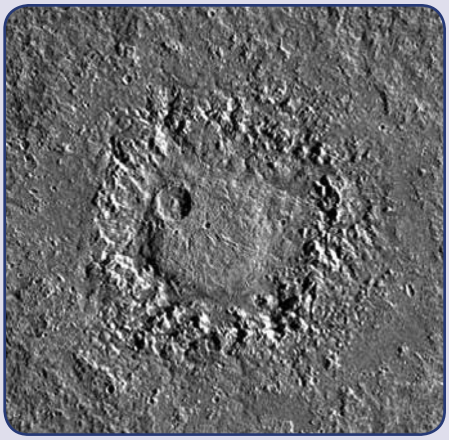
NASA/JPL

TWO TYPES OF TERRAIN cover Uranus' moon Miranda. Scientists think the big "racetrack" areas (called coronae) show where blobs of warm ice rose and stretched the crust, driven by tidal heating.



NASA/JPL/SSI

SEEN CLOSELY, Enceladus reveals lineaments hinting at icy tectonics, plus a handful of craters. The latter show the surface is not as young as, say, Io's, which is completely uncratered. This view takes in a width of about 200 miles (300 km). The complex interweaving fractures hint a long history of cracks, upwellings, and tension.



NASA/JPL

SPORTING A DOME in its center, Ganymede's Neith Crater shows features betraying a kind of "topographic relaxation," thanks to ice creep. The dome fills the center, a rough ring of hills marks the crater's central pit, and the crater's rim (nearly gone) appears as the outer edge of the smooth area. The dome spans about 27 miles (45 km).

surface, producing a kind of solid-state greenhouse. Solar warmth evaporates some nitrogen within the ice and pressurizes it. The gas then bursts upward through cracks, making geyser-style eruptions.

In contrast, Io's volcanos represent an extreme form of eruptions we see on Earth. As Io circles Jupiter, its orbit is tugged out of shape one way by its neighboring Galilean moons and the other by Jupiter. As Io flexes under these forces, friction rubs its rocks together and heats them to the melting point.

The Galileo spacecraft spotted more than 500 ionian volcanic sites, although most of the energy comes from just a handful that erupt with the greatest force. They shoot high-speed plumes of red and yellow sulphur dust hundreds of miles into the sky. Several eruption hotspots, discovered initially by the Voyagers in 1979–80, still were erupting for Galileo's cameras more than 15 years later. Scientists estimate Io is so eruptive, the moon resurfaces itself every few million years. It's a moon turning itself inside out.

Of shapes and surfaces

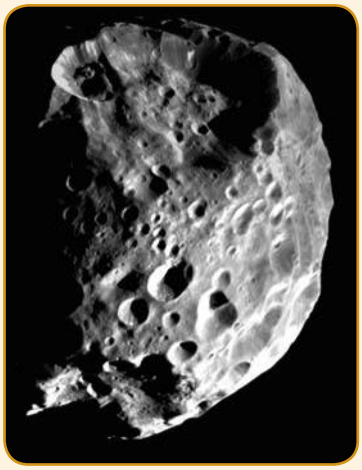
Earth's Moon is round, a result of both its size and the rock it's made of. Scientists know that above a certain mass, an object's gravity will compress the materials in its interior and overwhelm their strength. Big moons can squash themselves round.

But how big is big enough? At 250 miles (400 km) in diameter, Neptune's irregularly shaped moon Proteus is thought to lie just below this limit.

Many smaller moons have bizarre shapes, compounded by an accumulation of craters caused by meteorite impacts. A moon's surface provides clues to help scientists understand its internal processes. In the case of Saturn's moon Phoebe, its extremely pocked surface shows it has been hit so many times that its craters overlap to the point of saturation — and no internal process (such as volcanism) has erased them.

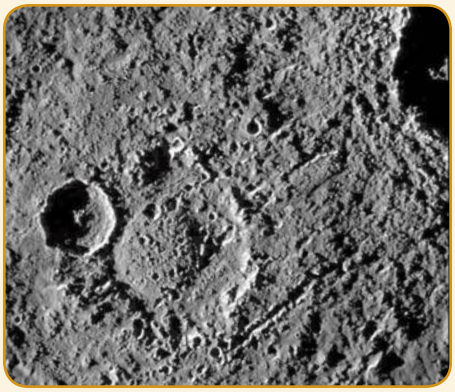
Phoebe looks battered, but Jupiter's moon Callisto has the most cratered surface of any

TARGET WORLDS



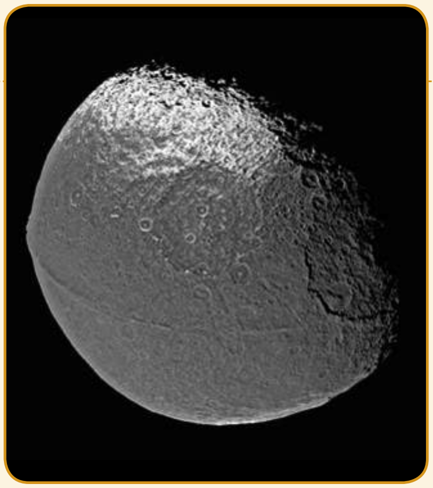
NASA/JPL/SSI

HEAVILY CRATERED, Saturn's Phoebe shows an ancient surface. Scientists think it was captured from the Kuiper Belt beyond Neptune when Saturn was forming.



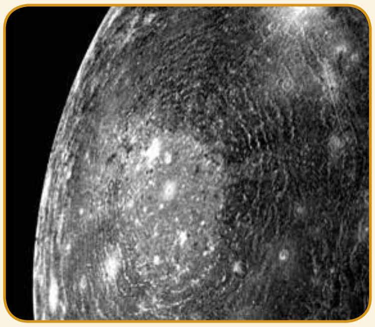
NASA/JPL

SEVERAL CRATERING EPOCHS are visible in this image of Har Crater on Jupiter's Callisto. The domed crater (Har) is about 30 miles (50 km) across and is the oldest feature. Sometime after Har formed, debris from Tindr Crater (top right edge) scarred the region. Last, the unnamed, fresh crater (left center) formed on Har's rim.



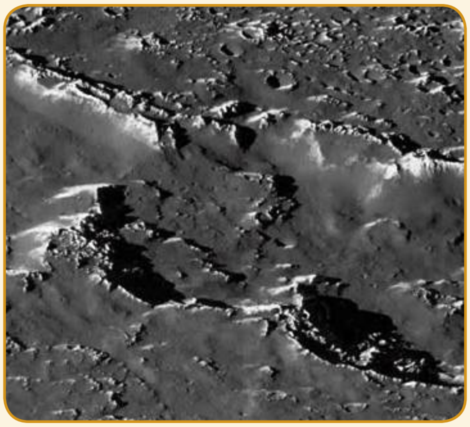
NASA/JPL/SSI

A TWO-FACED WORLD, Saturn's Iapetus is literally as black as pitch and white as snow: Its leading hemisphere wears a liberal coating of dark material. Two impact basins stand out (one seen at the right limb), plus many craters. Mystifying scientists, however, is the raised ridge that coincides almost exactly with the moon's equator. The ridge spreads about 12 miles (20 km) wide and stands 8 miles (13 km) high. Is it a mountain belt, or a crack filled with interior material, or what?



NASA/JPL

RIDGES AND RINGS surround Callisto's Valhalla impact basin. The central light region spans 200 miles (300 km).



NASA/JPL

JUMBLED TERRAIN marks part of a string of craters on Callisto, probably produced by impacts from a comet fragmented by Jupiter's gravity. The view is about 8 miles (13 km) across.

body in the solar system. Appearances suggest these moons have ancient surfaces, unchanged for billions of years.

In contrast, more active satellites like Jupiter's Europa, Saturn's Enceladus, and Neptune's Triton appear smoother because their craters are constantly being filled in or worn away by moving ice, volcanic lava, or other tectonic activity.

Less clear-cut is Uranus' moon Miranda, with its jumbled landscape. One part looks heavily cratered and old, while the other is young and geologically complex, with cliffs (one 6 miles [10 km] high) and grooves. Scientists think Miranda was smashed to bits several times and is now a half-grown world whose evolution froze mid-course.

Defying categories

Even similarly sized moons can have different environments. Saturn's largest moon, Titan, is the only satellite with a substantial atmosphere — heavier than Earth's by 60 percent.

Thin atmospheres have been found on two other moons, both large: Neptune's Triton and Jupiter's Io. Triton's atmosphere is mostly nitrogen, while Io's contains mainly sulfur dioxide.

Titan is in a category by itself, however. It is almost as large as Jupiter's moon Ganymede and the two bodies' masses and temperatures are similar. Yet Ganymede's thin, almost non-existent atmosphere of oxygen and hydrogen molecules couldn't be more different from Titan's. Scientists attribute this stark contrast to the differences in temperature where the moons were born — Titan took shape about twice as far from the Sun as Ganymede.

Measurements from Voyager 1 reinforced by Cassini's current data show that Titan's atmosphere is complex. Nitrogen dominates the gases, which include methane and other hydrocarbons also. Ultraviolet sunlight causes chemical reactions within this mix, producing an orange smog shrouding the moon.

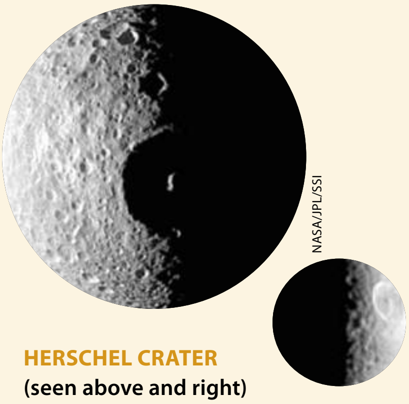
Infrared observations with the Hubble Space Telescope plus Earth-based radar data suggested that beneath the haze lay a rough landscape with continent-size

NASA/JPL/SSI

RING-SHEPHERDING MOON Prometheus maintains the inner edge of Saturn's F ring, along with Pandora, which guards the F ring's outer edge. Prometheus is a shard of ice and rock 63 miles (102 km) long.

NASA/JPL/SSI

STANDING FOR ITS PORTRAIT, Dione makes a small gray ball against Saturn's warm-hued disk. Dione's neutral color testifies to an icy surface.

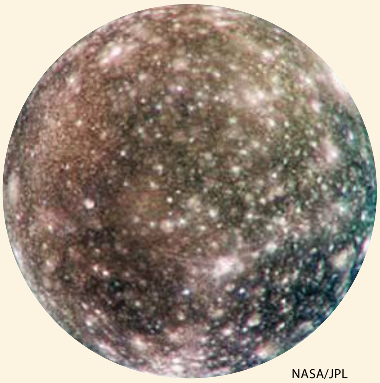


NASA/JPL/SSI

HERSCHEL CRATER (seen above and right) nearly ended Saturn's Mimas, as the impact almost smashed the moon. But instead, the feature, 80 miles (130 km) across, gave the moon an eerie resemblance to the Death Star from the movie *Star Wars*.

ESA

A CAPTURED ASTEROID, the martian moon Phobos is a heavily cratered rock. Like Mimas, it too suffered a near-fatal impact.



NASA/JPL

EONS OF IMPACTS have left Callisto's surface a network of bright craters on a darker background. Scientists think the moon has a layer of brine deep beneath its surface.

features. Cassini improved the view enormously by carrying filters for its cameras that could largely pierce the smog. Cassini also carries imaging radar.

For Titan, however, Cassini's most important "carry" was the Huygens lander. As it descended by parachute through Titan's hazy sky January 14, 2005, Huygens sent back images showing hills and plains, plus lakes and rivers of liquid methane. The images continue down to the surface, where fist- and thumb-size stones of dirty water ice litter the ground barely a yard in front of the camera. Except for Earth's own Moon, no other planet's moon has been photographed at ground level. See "Titan touchdown," *Astronomy*, April 2005.

Life on the moons?

Titan is a cold world, but its chemical resemblance to a young Earth intrigues scientists. With temperatures of –291° F (94 K), Titan's surface is too chilly for water to exist except as ice — and all life as we know it needs liquid water. Despite this, scientists are exploring Titan's organic chemistry and its possible links to life.

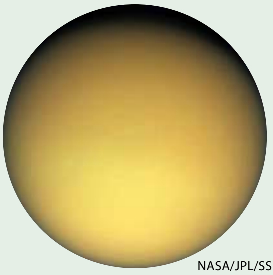
Other moons are suspected of being partly hospitable for life also. Thanks to detailed surveys by Galileo, Jupiter's ice-crusted moon Europa has attracted much attention. Europa's surface looks like broken glass stuck together with icy glue — tidal stresses open cracks continually and sheets of icy crust creep and then freeze together again. The best explanation for this stop/go movement is a slushy ocean beneath the icy outer shell.

In addition, magnetic measurements from Galileo show Europa has a changing magnetic field — further evidence of a subsurface ocean of salt water. Yet to the surprise of many astronomers, magnetic fields also surround Ganymede and Callisto, suggesting these moons have brine oceans beneath their surfaces too.

Scientists theorize Jupiter's far-reaching, powerful magnetic field sets up electric currents within salty oceans on these moons. The currents generate magnetic fields.

The presence of liquid water, warmed by tidal flexing, might mean life could

WEIRD WORLDS

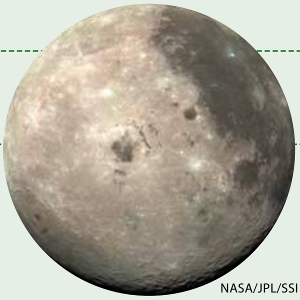


NASA/JPL/SSI

ORANGE SMOG hides the surface of Saturn's moon Titan, but special infrared filters can peer partly through the smog. Titan's atmosphere is 60-percent heavier than Earth's.

NASA/JPL

NEPTUNE'S MOON TRITON is the second moon in the solar system with a significant atmosphere. Scientists theorize that Triton's atmosphere is a polar cap migrating from the sunlit hemisphere to the nightside one. Sunlight evaporates surface ice (nitrogen mostly) to make the atmosphere. On the nightside hemisphere, the atmosphere recondenses on the surface as frost and ice.

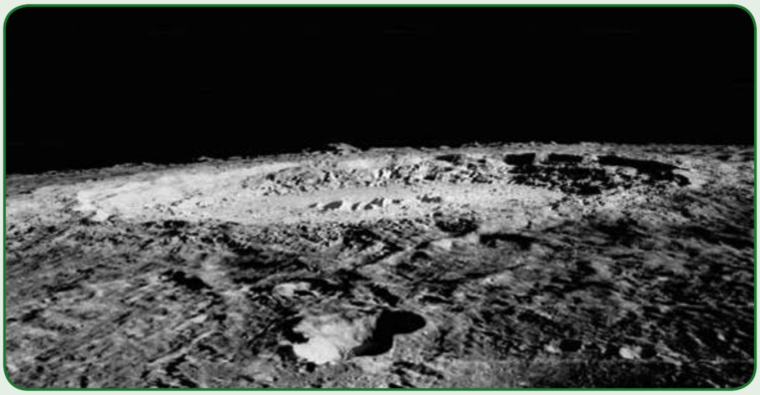


NASA/JPL/SSI

A HYBRID BODY, Earth's Moon is the result of impacts and volcanic action. This view centers on the Orientale impact basin, 600 miles (1,000 km) across and with lava filling both its center and areas between its rings. At right lies Oceanus Procellarum, the vast lava expanse on the Moon's northwest side. At lower left is the large, slightly darkened region of the South Pole-Aitken basin, the Moon's largest and oldest known impact basin.

NASA/JPL

THE "CIRCUS MAXIMUS" is a multi-ring impact basin on Titan about 270 miles (440 km) in diameter. This image, taken with the Cassini spacecraft's radar, shows the first impact structure identified on Titan. A widespread lack of craters suggests Titan has a geologically young surface.



NASA

A WIDE, SHALLOW BOWL, Copernicus Crater on the Moon spans 58 miles (93 km). Scientists date the impact that created it to about 800 million years ago. This view, taken by the Lunar Orbiter 2 spacecraft in 1966, looks north toward Mare Imbrium.

exist in these moons' oceans. To obtain direct evidence of life, however, calls for new spacecraft able to investigate the moons more closely. Unfortunately, NASA's mission to Europa, the Jupiter Icy Moons Orbiter (JIMO), has been canceled.

Pushy fragments

Cassini is providing scientists with fascinating images of Saturn's rings and possible new moons. The shape of Saturn's F ring is controlled by two shepherd moons, Prometheus and Pandora, whose gravity works together to weave complex structures in the ring.

Moons such as Jupiter's Metis, Adrastea, Thebe, and Amalthea actually contribute material to the rings themselves. When these ring-moons are struck by meteoroids, they shed dust and rocky pieces, which then become sucked into the rings.

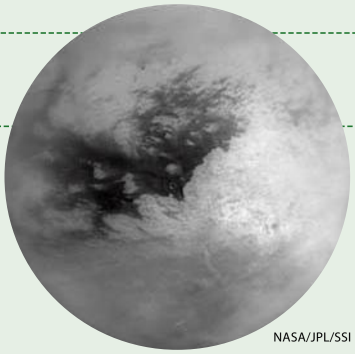
Other moons exhibit strange behavior: Saturn's Janus and Epimetheus regularly swap orbits, and other saturnian moons trail their larger companions.

Origins

Studying moons isn't just about observing their features, but also understanding their origins. With the exception of Neptune's large satellite Triton, all the giant planets' major moons are in orbits close to their planet's equatorial plane. They also orbit prograde — in the same direction the planet rotates. With such well-ordered orbits, the most likely formation mechanism for these regular satellites is that they condensed from a disk of gas and dust around each planet.

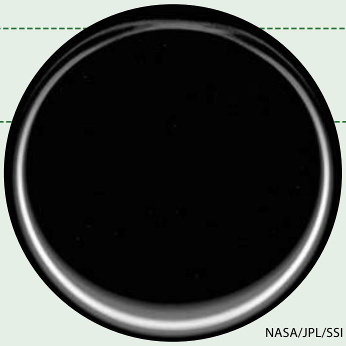
In contrast, Triton is the only large satellite in the solar system to orbit retrograde — in the opposite direction to the planet's rotation. Scientists think Triton is an ex-Kuiper Belt object that formed beyond Neptune and was captured by it somehow.

Another way to become a moon is to start life as an asteroid or comet. The appearance of the two small, battered martian moons, Phobos and Deimos, suggests they may have originated as asteroids and been captured by Mars. Without a way of rewinding the tape, however, answers to questions like these can never be certain.



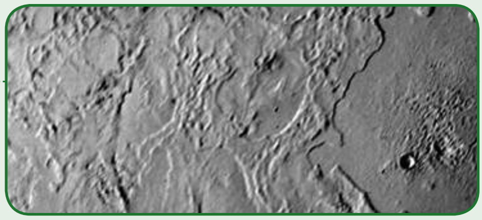
NASA/JPL/SSI

FILTERS AND PROCESSING show surface details on Titan. Scientists think the dark areas are lakes or seas of methane, but they do not show the bright sun-glint that a liquid surface would.



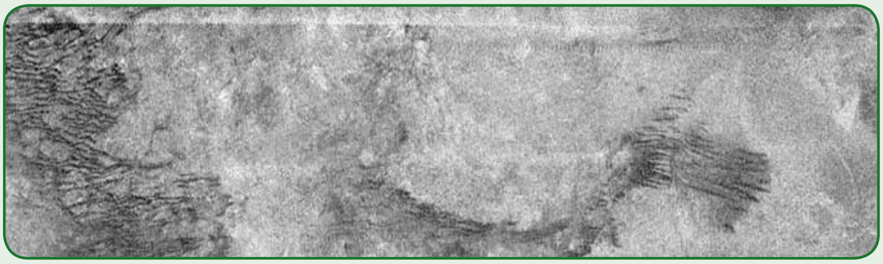
NASA/JPL/SSI

TITAN'S NIGHTSIDE reveals the atmosphere as a bright ring. In the north (top), the atmosphere shows a second bright layer, not yet understood by scientists.



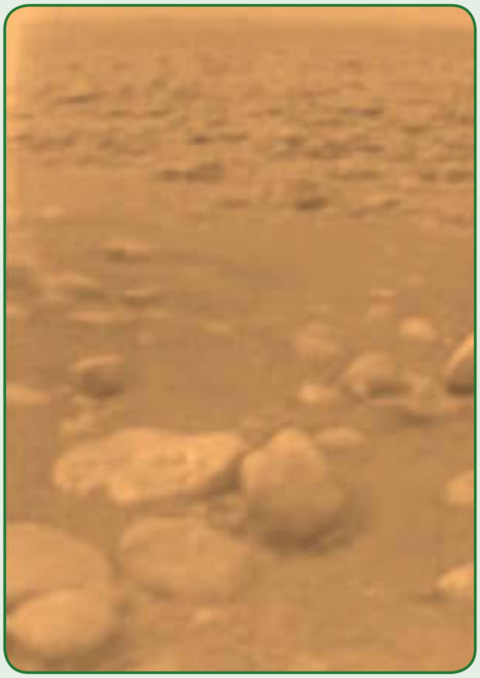
NASA/JPL

LOW-ANGLE SUNLIGHT brings out features near this large, subdued impact basin (right edge) on Triton. The basin spans about 160 miles (250 km), and only one fresh impact crater can be seen.



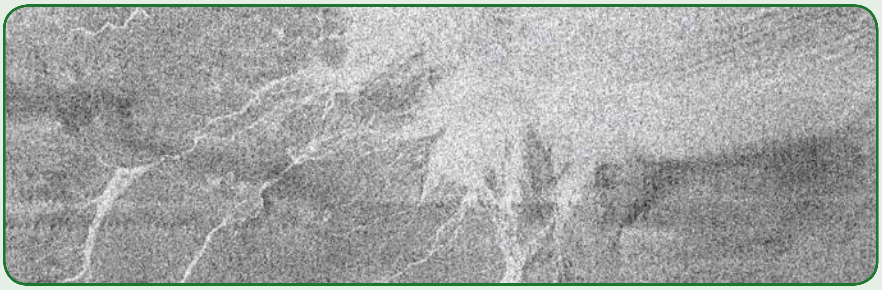
NASA/JPL

DARK LINES RUN across this Titan radar image that spans about 200 miles (300 km) top to bottom. The lines may be linear dunes.



ESA/NASA/UNIVERSITY OF ARIZONA

TOUCHDOWN ON TITAN! The Huygens lander's camera shows fist-size "rocks" of water ice extending toward a hazy horizon. The rocks' rounded appearance suggests they have been worn smooth by stream flow.



NASA/JPL

WHITE STREAKS may be streams or riverbeds in this radar image of an area near Titan's Circus Maximus. Scientists are trying to understand the chemistry and weathering of the hydrocarbons that cover the moon's surface.

Moonfinding

Many moons remained unknown until found by passing spacecraft, and this wasn't just due to their small size. Dark moons are hard to see, especially with there is something bright nearby.

Six of Neptune's moons, including Proteus and Larissa, are among the darkest objects in the solar system. Lost in the glare from Neptune, they were not discovered until Voyager 2 flew closely past the planet in 1989.

More recently, in 2003 scientists used the Hubble Space Telescope to discover two new moons of Uranus in an area previously thought to be empty space. These moons are so dark they were missed by Voyager 2. At nearly 1.7 billion miles (2.8 billion km) from Earth and measuring only 8 and 10 miles (12 and 16 km) in diameter, their discovery testifies to the incredible telescope power now available to planetary scientists.

Luckily for astronomers, not all moons are dark. Icy moons like Triton and Europa reflect much of the sunlight that hits them, which makes them appear bright and also lowers their surface temperatures.

Saturn's moon Enceladus is even more reflective — the clean water ice covering its smooth surface makes it one of the shiniest objects in the solar system. Nearly 100 percent of the sunlight falling on Enceladus reflects from it.

Exploration is far from over, and not only with distant moons. The European Space Agency's SMART-1 is orbiting our own Moon. It will map the chemical composition of the lunar surface more accurately than before and look for water ice at the poles.

Ground- and space-based studies of solar-system moons will continue, and new technologies should enable more sophisticated investigations. Learning is an ongoing voyage of discovery, and one thing is certain: The more we learn, the more questions we will have. A

ONLINE EXTRA For the lowdown on *all* the solar system's 141 moons, visit www.astronomy.com/toc

{ GALACTIC ASTRONOMY }

Dark threat

ADOLF SCHALLER

Could an unseen stellar assassin cause mass extinctions on Earth? /// By Bruce Dorminey

Seventy percent of all stars appear to have companions. Yet most astronomers take it for granted our own star always has been a lone wolf — separated at birth from the cluster in which it formed and drifting gradually from its stellar brethren into an interstellar sea of reddish M dwarfs ever since.

Nearly 5 billion years after its formation, a few of the Sun's estimated 100 original stellar companions still populate the neighborhood. The most prominent of these include Alpha Centauri, Tau Ceti, and Wolf 359. We're still debating whether our Sun's defiance of the partnership odds is the result of a stellar marriage gone sour or is somehow linked to our planetary system's intrinsic habitability. Has our Sun always been single? Or, even now, is there a low-mass, substellar mistress lurking just out of view, beyond the outer fringe of the cometary Oort Cloud?

In young clusters, gravitational interactions can cause protostellar systems to resemble a bumper-car ride. Once the more mature systems escape from their stellar nurseries, many seem to form stable planetary systems.

In some instances, these occur in tandem with a stellar companion; in others, as a single entity like our solar system. But that doesn't mean they don't feel the effects from nearby stellar intruders. Such passing stars can strip a young planetary system of its outer members or cause perturbations in its Oort Cloud — a chaotic zone of cometary debris that, in our solar system's case, extends more than a third of the way to the nearest star, Proxima Centauri.

Sedna, the first planetoid ever detected in the inner regions of the Oort Cloud, makes its way around the Sun in a highly inclined, highly eccentric orbit that takes 10,500 years to complete. It gives credence to the fact that our Sun formed in a loosely bound, open star cluster. Scott Kenyon, an astronomer at the Smithsonian Astrophysical Observatory in Cambridge, Massachusetts, believes Sedna may have been lifted from its original position somewhere near Neptune's orbit to its current location when dynamical interactions ripped away one of the Sun's original cluster companions only 50 to 100 million years after our star's formation.

Computer models indicate the passing stellar culprit would have come within perhaps 150 astronomical units, or roughly 4 times the distance between Pluto and the Sun. (One astronomical unit, or AU, is the average distance between the Sun and Earth, or approximately 93 million miles.) The interaction also may have created the unnaturally sharp edge at 50 AU astronomers have observed in the outer edge of the Kuiper Belt, a band of cometary debris left over from the solar system's formation.

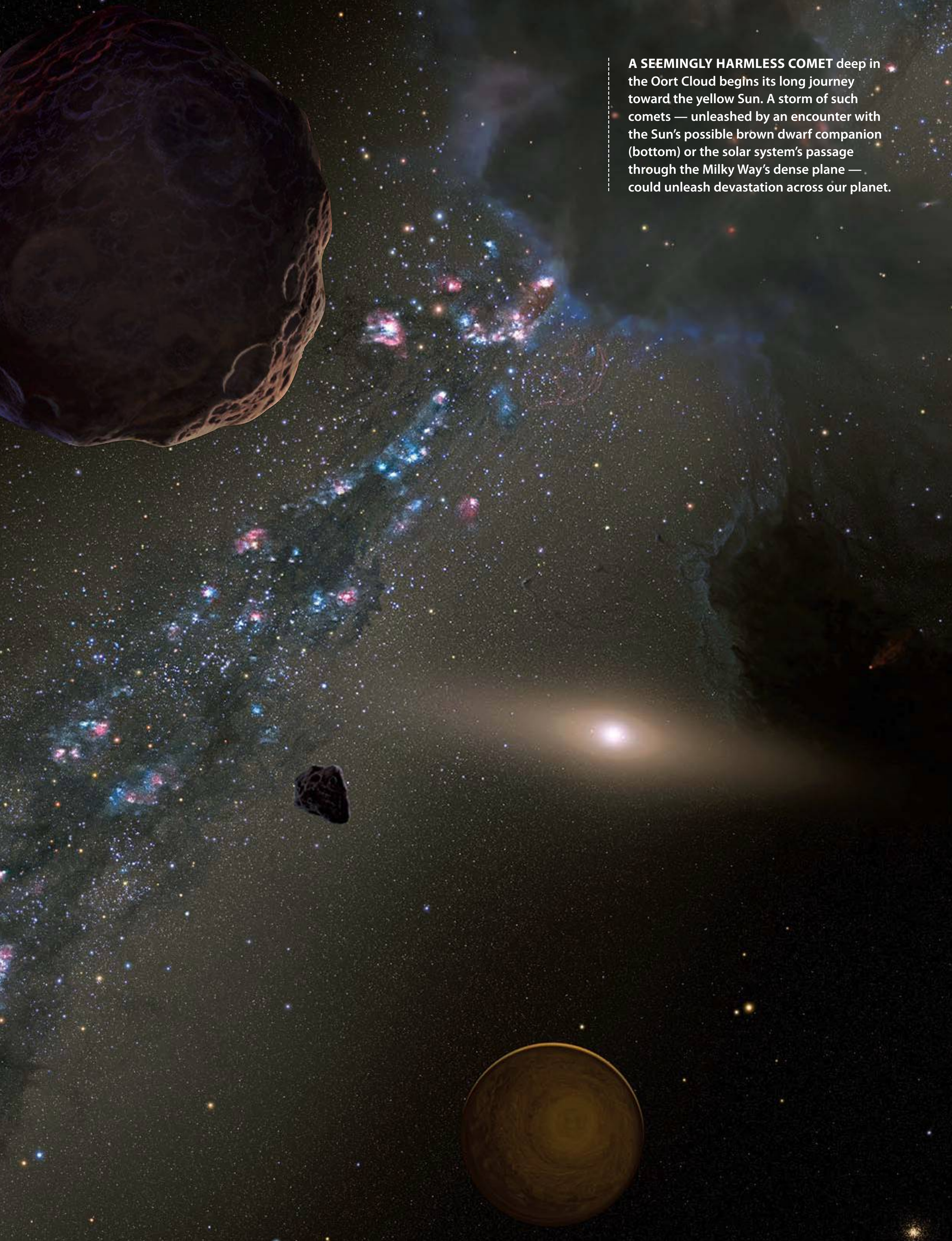
Those early rough-and-tumble days are over. The next close stellar approach will involve Gliese 710, a small red dwarf currently some 60 light-years away in Ophiuchus. In less than 1.5 million years, it should pass within a light-year of the Sun. Astronomers estimate the passage will unleash 2.5 million Oort Cloud comets to move into new Earth-crossing orbits, which in turn will arrive in our vicinity over a period of 2 million years.

But what if the Sun has a hidden stellar companion still out there, causing trouble on a periodic basis?

A period to extinctions

In February 1984, University of Chicago paleontologists David Raup and J. John Sepkoski published a short paper in the *Proceedings of the National Academy of Sciences* announcing that extinction rates in Earth's geologic past appeared to be periodic. Raup and Sepkoski attributed this observed periodicity to galactic forces acting on our surrounding cometary reservoir as we travel through the Milky Way.

Later in 1984, University of California at Berkeley physicist Richard Muller co-authored a paper in *Nature* that attributed



A SEEMINGLY HARMLESS COMET deep in the Oort Cloud begins its long journey toward the yellow Sun. A storm of such comets — unleashed by an encounter with the Sun's possible brown dwarf companion (bottom) or the solar system's passage through the Milky Way's dense plane — could unleash devastation across our planet.

GERALD RHEMANN AND FRANZ KERSCHE

COMET HYAKUTAKE, **a spectacular 1996 visitor from the Oort Cloud, passed within 10 million miles of Earth. If such a comet actually hit us, it would have dire consequences for many of our planet's species.**

the reported 26-million-year extinction periodicity to our own G2 star having an unseen stellar companion. The hypothetical object was soon dubbed "Nemesis." Until recently, there has been no way to prove or disprove the Nemesis theory.

But the Two Micron All Sky Survey (2MASS), a ground-based near-infrared survey which spent 4 years scanning 99.998 percent of the sky and collecting nearly two million images from both the Northern and Southern Hemispheres, would have been sensitive to such a nearby M dwarf if it were there. It wasn't.

Bruce Dorminey *is a France-based science writer and author of* Distant Wanderers: The Search for Planets Beyond the Solar System *(Springer-Verlag).*

However, 2MASS did find brown dwarfs — failed stars ranging from about 12 to 75 Jupiter masses and thus lacking enough mass to ignite the hydrogen in their cores and become full-fledged stars — are more common as widely separated companions to Sun-like stars than anyone had imagined. They typically show up as companions to G-type stars at distances of hundreds to thousands of AU.

"In a fragmenting protostellar cloud, there's a hierarchy of different sizes where low-mass objects are much more frequent," says Davy Kirkpatrick, an infrared astronomer at Caltech. He has been studying low-mass stars and brown dwarfs for the past 15 years, and headed the quality assurance team for 2MASS. "The weaker member gets shot out first. That may be why brown dwarfs around G-type stars are farther out rather than closer in. So, a star that we originally thought was single will often actually turn out to be a double."

2MASS also uncovered an M-dwarf companion to Upsilon Andromedae, a star with a known planetary system. So logic followed that if 2MASS could find hidden M dwarfs and even lower-mass objects at large distances from other stars, it ought to be able to pick off a Nemesis-type companion to our Sun.

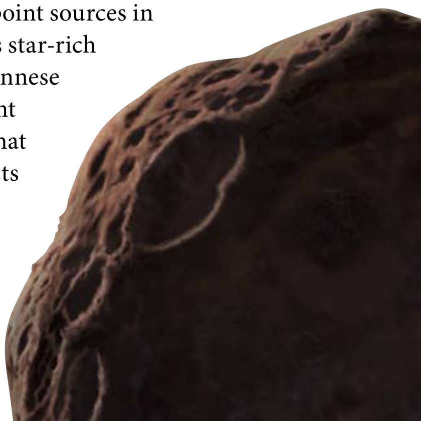
After Kirkpatrick ruled out the possibility that Nemesis could be an M dwarf, he moved his search for such a companion into the realm of truly low-mass companions. To help with the search, last summer Kirkpatrick and the 2MASS team enlisted Francesca Colonnese, an undergraduate astrophysics major at Caltech, to spend 6 weeks sifting through reams of data looking for Nemesis.

Let the search begin

Colonnese filtered out known comets and asteroids as well as extragalactic sources from the 2MASS search program. Yet she still found herself poring over nearly 4,600 objects on black-and-white images for 8 hours a day, 5 days a week, flagging point sources that needed to be verified as matching known objects. An object with a high proper motion, or movement across the sky, would need further verification to make sure it was a known source and not the high-proper-motion Nemesis object.

Colonnese initially searched to see if any objects immediately failed to match up with sources cataloged in earlier optical surveys. Because 2MASS images are snapshots of a given piece of sky at one instant in time, she had to compare hundreds of images of candidate Nemesis objects with images from earlier digitized photographic surveys. That was the only way to see if any flagged 2MASS objects were moving at suspiciously high proper motions.

Colonnese searched through images for objects so faint they could lie up to 20,000 AU from the Sun. And the search was sensitive to objects from M dwarfs to the coolest, faintest brown dwarfs known. Although she found many unknown point sources in the galaxy's star-rich plane, Colonnese is 90-percent confident that of the objects she analyzed, none could be Nemesis.



"We know Nemesis would have a proper motion that didn't look like one of these generic background stars," says Colonnese. "The large majority of the 2MASS objects I looked at hadn't moved at all. So, Nemesis would have to be going out of its way hiding somewhere for us not to have detected it."

An extinction machine

Most astronomers are only too happy to agree. From the start, at least publicly, few took the Nemesis idea seriously, even if privately they occasionally alluded to its possibility. But Michael Rampino, a geologist at New York University who has been studying Earth's cratering record for the past 25 years, is still looking for an astrophysical smoking gun.

He believes there are periodicities in Earth's extinction record, but on scales roughly between 25 and 35 million years, rather than the more precise, previously held figure of about 26 million years. Rampino points to at least three well-documented impact records going back some 100 million years. The first stems from two 60-mile-wide craters dating from about 35 million years ago, one under Chesapeake Bay and the other in Popigai, Siberia.

But the best known impact is the one thought to have precipitated the demise of the dinosaurs 65 million years ago. Known as the Cretaceous-Tertiary (K-T) extinction, it coincided with the impact of a 6-mile-wide asteroid that hit north of the Yucatán coast, near Chicxulub, Mexico.

The telltale signature of iridium (a non-reactive white metal) — more abundant in cosmic material than on Earth — indicates the bombardment wreaked general havoc, causing an impact winter, a destructive greenhouse effect, and torrents of acid rain. Rampino believes he sees signs of a third previous event, or events. Although no major crater has shown up in the cratering record yet, several small craters point back to a catastrophe some 95 million years ago.

"You can go back three or four impact events, depending on errors in the geological record and dating," says Rampino. "If one of these were to hit now, we are looking at impacts that would cause the end of civilization and make 90 percent of all species extinct."

Yet Rampino doesn't believe a stellar companion caused these Oort Cloud perturbations. Instead, he thinks the natural vertical oscillation of our solar system through the dense mid-plane of the Milky Way Galaxy is what disturbs the Oort Cloud.

Located in the Orion Spur, which branches off the local Sagittarius-Carina spiral arm, the Sun currently orbits the galactic center roughly every 225 million years. This motion is taking us in the direction of the constellation Hercules

/// COMET STORM A'COMING?

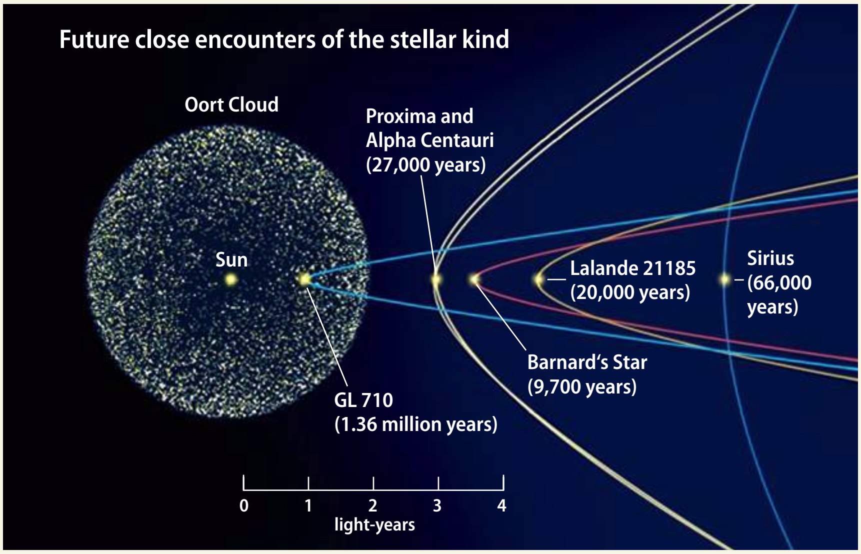
The solar system can be a scary place. Wayward asteroids and comets occasionally strike Earth, often with dire consequences for life on the planet. Scientists have found evidence that mass extinctions may occur periodically, and suggest a rain of comets from the distant Oort Cloud could be the trigger. Some astronomers have proposed this regularity could be explained by a brown-dwarf companion to the Sun, or to the cyclical passage of the solar system through the Milky Way's dense mid-plane.

But not all comet showers need be periodic. A star's random close encounter with the solar system could just as easily initiate a comet downpour. A team of researchers led by Joan García-Sánchez of the Jet Propulsion Laboratory combined observations made from the ground with data from the Hipparcos satellite to see which stars will make a close pass in the next 10 million years.

The team found Sirius, the brightest star in the sky, will come within 7.5 light-years of the Sun in 66,000 years. Barnard's Star, which currently moves across the sky faster than any other, will approach within 3.7 light-years in 9,700 years. And Proxima Centauri, now the closest star to the Sun, will graze within 3.1 light-years in 27,000 years. Close calls, but none should disturb the Oort Cloud.

The same can't be said of Gliese 710, an obscure star that has its sights set on our solar system. In 1.36 million years, Gliese 710 will penetrate the Oort Cloud when it dips within 1.1 light-years of the Sun.

With a mass about half that of the Sun, Gliese 710 will have a profound effect. García-Sánchez's team estimates the encounter could perturb nearly 2.5 million comets into Earth-crossing orbits. The storm will spread out over about 2 million years, so an average year will see only one extra long-period comet. Still, our distant descendants will have to keep their eyes on the sky, perhaps with a mix of wonder and concern. — *Richard Talcott*


Future close encounters of the stellar kind
Oort Cloud
Proxima and Alpha Centauri (27,000 years)
Sun
Lalande 21185 (20,000 years)
Sirius (66,000 years)
Barnard's Star (9,700 years)
GL 710 (1.36 million years)
0
1
2
3
4
light-years

ASTRONOMY: ROEN KELLY

ABOUT 1.36 MILLION YEARS from now, the star Gliese 710 will penetrate the Oort Cloud and send 2.5 million comets into the inner solar system.

A TANGLED WEB OF STARS punctuates the Milky Way Galaxy's central regions. Francesca Colonnese had the unenviable task of searching similarly dense 2MASS images looking for a faint, moving dot that would signify Nemesis.

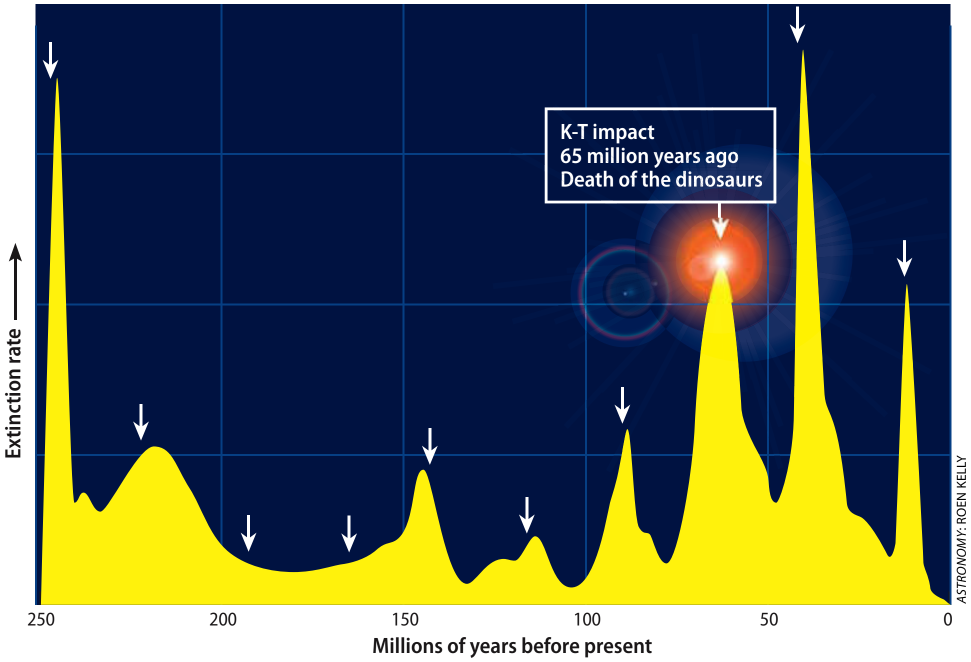
faster than the spiral arms through which we are moving.

But our solar system also has a secondary motion that takes us north and south of the galactic plane, not unlike a cork bobbing on a gently rippling lake. At the moment, the Sun lies nearly 50 light-years north of the galactic plane and travels at a rate of 4 miles per second. It appears to have crossed the middle of the galaxy's plane some 2 million years ago. It's this vertical motion through the relatively dense mid-plane that Rampino believes might cause perturbations in the Oort Cloud, and with it periodicities in Earth's cratering record.

If so, the impact events caused by such perturbations should start a few million years after the Sun passes through the galaxy's mid-plane. The question remains, however, just how much farther north of the plane we will go before we start heading south again. For each full vertical oscillation, our solar system crosses the mid-plane twice. The period between passages depends in large part on the mid-plane's density. Astronomers estimate this region contains 0.003 solar mass per cubic light-year, which would make the Sun reach a maximum height of 290 light-years above the galactic plane. That, in turn, means the solar system crosses the mid-plane roughly once every 41.7 million years, a few million years longer than Rampino's maximum estimate on the cratering periodicity.

Leo Blitz, an astronomer at the University of California at Berkeley, has a long-standing interest in the Sun's interactions with the spiral arms. He believes the density in the spiral arms could be 10 to 30 percent higher than the current estimates, but that would never be enough to trigger an incoming shower of new comets. It's a view Kenyon echoes.

"I don't think the density changes enough to matter," says Kenyon. "But if this vertical motion changes the gravita-



ASTRONOMY: ROEN KELLY

EARTH'S FOSSIL RECORD shows large numbers of species seem to disappear at regular intervals. The arrows indicate the roughly 30-million-year period some scientists claim.

2MASS/UMASS/IPAC-CALTECH/NASA/NSF

tional force of the galaxy on the Oort Cloud, that might make a perturbation. And we don't really know enough about the structure of the galaxy to rule that out. Close to a spiral arm, we get a little more of a tidal torque from the galaxy than we do at other times, so that might change the Oort Cloud enough to send a few extra comets in."

A smaller brown dwarf?

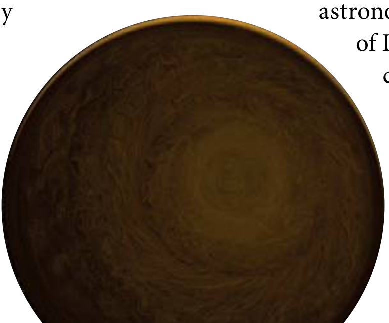
No matter how improbable, the culprit could be an even smaller brown dwarf. Such an object could exist in an oddly shaped orbit around the Sun that keeps it too far away and too faint for 2MASS to have seen. Kirkpatrick believes this brown dwarf could be no bigger than 40 Jupiter masses; otherwise, Colonnese's 2MASS search would have picked it up.

If such a low-mass brown dwarf does exist as our Sun's Nemesis, it would have formed like any other low-mass binary companion. But somehow it would have become skewed into a 30-million-year-long solar orbit, likely by yet another encroaching star. Such a long, irregular orbit would bring this tiny Nemesis as close as 10,000 AU from the Sun, but at its farthest point, it would be a whopping 170,000 AU. That's an incredible distance — well beyond the edge of the Oort Cloud.

"It would be hard to spot because anything on such an elliptical orbit spends most of its time far away," says Mike Brown, a planetary scientist at Caltech and one of Sedna's co-discoverers. "But a 40-Jupiter-mass object could definitely upset the inner Oort Cloud enough to cause these bombardments."

Even so, the Nemesis idea is on life support. It likely will be written off when NASA collects data from a space-based follow-on to the 2MASS survey. The Wide-field Infrared Survey Explorer, now in its definition phase and with a proposed launch date in 2008, would be able to spot these exotic brown dwarfs at distances of almost 10 light-years. Even with the current evidence, the astronomical community's skepticism concerning our Sun's possible partner may have been warranted all along. There are worse fates than being single. In the case of our Sun, the result remains spectacular.

"We have a very orderly, stable solar system with no companions to mess anything up," says John Gizis, an astronomer at the University of Delaware. "That in itself could be a selection effect for complex life. And with one in three stars being single, those odds aren't bad." ◼

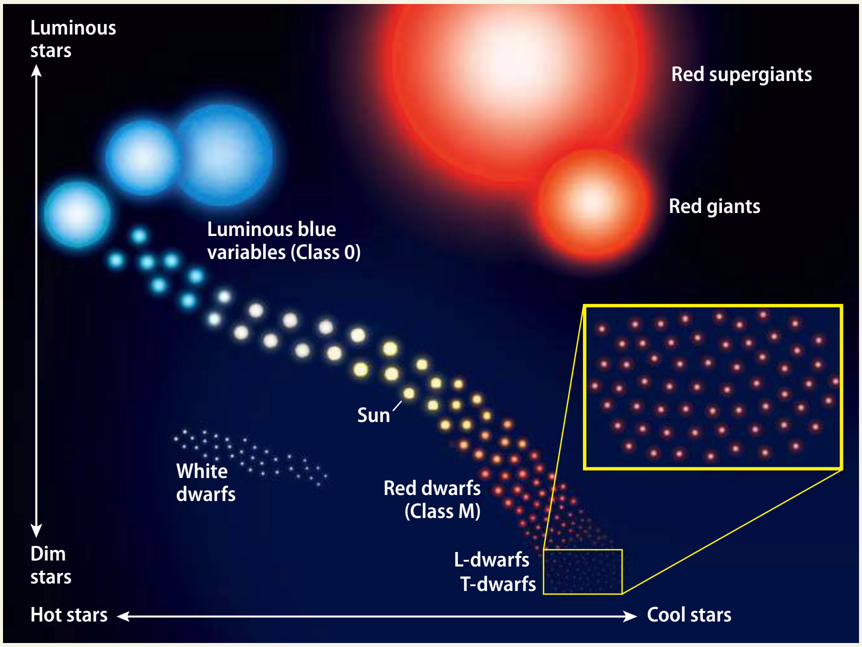


/// A TOUCH (OR TWO) OF CLASS

For generations now, astronomy students have learned how scientists classify stars according to temperature and color with the handy mnemonic device: "Oh, Be A Fine Girl (or Guy), Kiss Me." The first letters of those seven words describe the sequence from massive stars that shine hot and blue (class O) to lightweight stars that glow cool and red (class M).

The spectral sequence stood the test of 80 years. Within the past decade, however, technological advances have forced astronomers to revise it. Or, more accurately, add to it. The cooler a star's surface, the less energy it radiates. M stars have surface temperatures that range down to about 3,100° Fahrenheit — so cool that, until the late 1990s, astronomers basically couldn't see stars any cooler and fainter.

But Nature doesn't stop there. It creates objects even smaller, cooler, and fainter than M dwarfs; objects that began turning up in the 1990s. The discoveries led astronomers to add two classes — L and T — some of which likely are brown dwarfs. (The letters were chosen because they were among the few not being used for other purposes.) L dwarfs have surface temperatures from about 1,900° to 3,100° F, and T dwarfs extend down to 900° F. — *R. T.*



ASTRONOMY: ROEN KELLY

TRADITIONAL SPECTRAL CLASSES **have been expanded in the past few years to include L and T dwarfs, objects even smaller, cooler, and fainter than M-dwarf stars.**

{ PROFILE }

Cosmic music man

As the universe sings, Alex Szalay listens for answers to fundamental cosmological questions. /// BY STEVE NADIS

During the fall of 2003, Alexander Szalay was busy "cutting" two CDs — one containing Sloan Digital Sky Survey (SDSS) data and another featuring his rock band. Such is the life of this full-time astronomer and occasional rock star who grew up in Hungary.

As a chaired professor of astronomy at Johns Hopkins University in Baltimore, the database "guru" for the SDSS, and project director for the National Virtual Observatory, Szalay has more than enough to stay busy. "I love every minute of what I'm doing," he says, "but I wish I had another 24 hours in a day to do music."

Prelude

These days, astronomy comes first for Szalay. But back in the 1970s, while still in Hungary, he led a dual life: cosmology by day, rock 'n' roll by night. In 1974, he and four others, including his brother Andras — also a physicist — formed their band, Panta Rhei. The band's name comes from the sixth-century B.C. Greek philosopher Heraclitus' saying, "It's impossible to step into the same river twice," meaning "everything changes."

In 1982, the band broke up, but it still gets together occasionally to record. Panta Rhei was successful in Hungary, selling more than 100,000 albums and touring throughout Eastern Europe regularly.

Szalay, 56, grew up in Hungary. Both of his parents were nuclear physicists, as was his grandfather, and he lived with his parents on the site of a small nuclear physics institute in Debrecen, Hungary.

After earning a bachelor's degree in physics in 1969 from Kossuth University — now the University of Debrecen — he received a master's degree in theoretical physics and a doctorate in astrophysics from Eotvos University in Budapest, in 1972 and 1975, respectively. During the following 5 years, Szalay continued to juggle physics and music — a lifestyle that afforded him little sleep.

By 1980, he had to decide between his two passions. The band had gone as far as it could playing in university clubs in Hungary and neighboring countries. "To do more [in music], I would have had to give up physics," Szalay says.

Meanwhile, he was under pressure from his parents to drop music. His father, in particular, considered rock 'n' roll a complete waste of time.

Szalay chose physics and looked for a postdoctoral position in the United States or Western Europe. Unfortunately, he did not have any luck finding one. "I decided to give it 1 more year," he says. "If I didn't get a good job offer, I'd stay in music."

Cosmological connection

Szalay's employment difficulties may have stemmed from his research specialty — the cosmological implications of massive neutrinos — which he pursued under the supervision of the famous Soviet physicist Yakov Zel'dovich. Given cosmology's speculative nature at the time, this line of work was considered dubious, keeping Szalay on the fringes of astrophysics.

His fortunes changed dramatically in 1980, when evidence of neutrino mass emerged. Szalay suddenly became a coveted speaker at scientific gatherings. He impressed Joseph Silk, a University of California at Berkeley cosmologist, at a Warsaw conference where Szalay gave a series of talks.

Silk offered Szalay a job, as did University of Chicago astrophysicist David

MULTI-TALENTED ALEX SZALAY regards the universe as the ultimate musical instrument.

KYLE BERGNER PHOTO/GUITAR ILLUSTRATION BY *ASTRONOMY*: ROGER GROAT/ILLUSTRATION IMAGE: NASA, HOLLAND FORD (JHU), GARTH ILLINGWORTH (UCO/LICK OBSERVATORY), NARCISO BENITEZ (JHU), MARK CLAMPIN (STSCI), GEORGE HARTIG (STSCI), THE ACS SCIENCE TEAM, AND ESA

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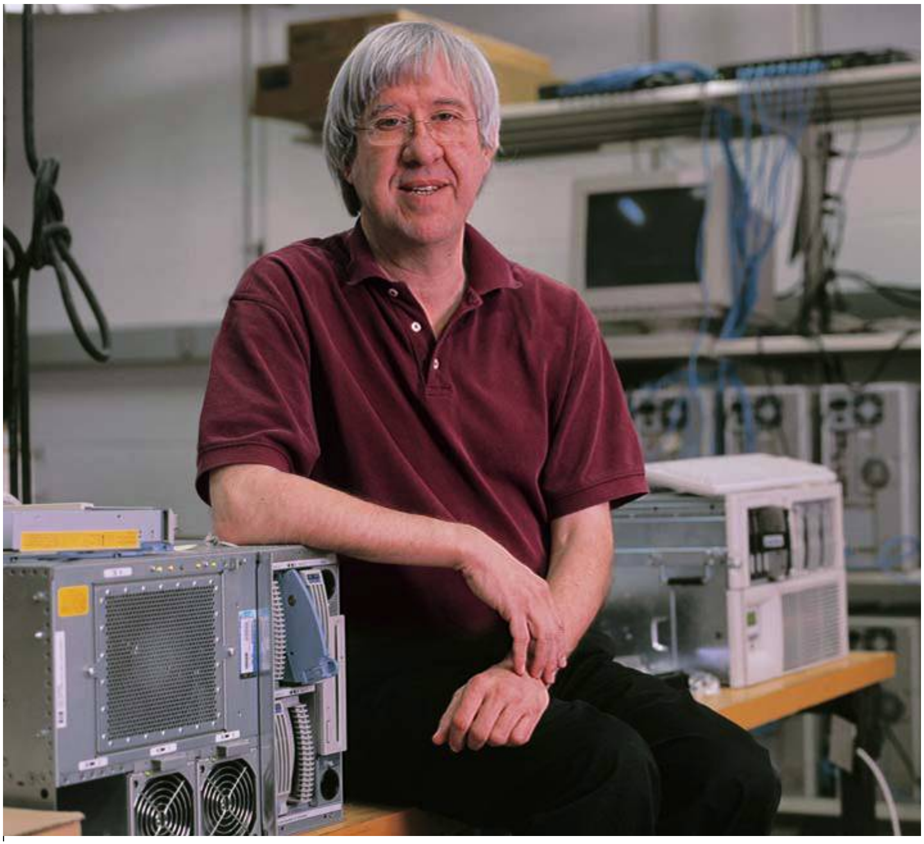


KYLE BERGNER

FOR THE SDSS TEAM to understand the extreme amount of data the survey is collecting, Alex Szalay had to refine data processing.

Schramm. Szalay accepted both offers, shuttling among Berkeley, Chicago, and Hungary during the next several years until he joined the Hopkins faculty in 1987 — where he was finally able to settle down with his wife and son.

Soon thereafter, as a result of his career decision, instead of playing music in front of screaming fans, he was playing an audio representation of galaxy distributions to scholars at a Tokyo conference. Those are the compromises a rock star makes upon entering the ivory tower of academia. Yet Szalay has somehow managed to keep active on the music front: Panta Rhei released new albums in 2000 and 2002.

Few fellow astronomers know about Szalay's musical efforts. And that's just as well, he says. "I don't want to be known as the astronomer who does music or as the musician who does astronomy. If you play music, it has to be good enough to stand on its own. The same holds for astronomy. Achieving something in one area doesn't give you a break in another area."

Steve Nadis *is a science writer and frequent* Astronomy *contributor. He lives in Cambridge, Massachusetts.*

Resonant ties

Despite their apparent differences, Szalay doesn't regard astronomy and music as separate. "Both scientists and musicians take new ideas on the road. They go on tour and perform." Writing a scientific paper, says Szalay, "is a creative process, comparable to writing a song. Although you have certain elements in mind to start with, you can't predict the outcome."

Collaborating with a fellow astronomer is like "jamming" with your band, he adds. When Szalay works with University of Toronto astrophysicist Dick Bond, "there's a deep, multi-level communication between us. One person says a word and the other knows exactly where he's going. The same thing happens in music: You play a note and your partner takes off on it."

Szalay is by no means the first person to perceive connections between the two disciplines. Pythagoras, the sixth-century B.C. Greek philosopher and mathematician, suggested the existence of the "music of the spheres" — a harmonious humming, imperceptible on Earth, that is produced by the orderly movements of celestial bodies.

Johannes Kepler, along with many other astronomers, embraced the Pythagoras concept, but Szalay wants no part of it. Szalay would rather not be associated with the ancient Greek view of the heavens. Yet oddly enough, the main cosmological problem he's pursued for the past couple decades is a musical one: trying to figure out the universe's resonant frequency.

Music of the cosmos

A musical instrument such as a guitar or drum has a characteristic, or "resonant," frequency at which it naturally vibrates. This frequency's exact value depends on the instrument's size, shape, and material. Parts of the instrument — whether guitar strings or drum head — vibrate at particular frequencies, creating harmonics roughly at octave intervals. What you hear is the sum of the fundamental frequency — the note the musician plays — and the higher harmonics. The overall sound reflects the relative strengths of these components.

Shortly after the Big Bang, says Szalay, the universe was like a musical instrument — a big noisy expanse filled with hot, dense ionized "fluid," or plasma, of matter and photons. Gravity compressed the plasma, but being under high pressure, the plasma bounced back, producing sound waves of different frequencies that reverberated through the cosmos.

These sound waves in the plasma were composed of expansion and compression regions which are characterized by subtle variations in mass density.

Because the waves come only in distinct sizes (or wavelengths), there is a pattern in the clumpiness they create (see "The cosmic Slinky toy" on page 50 for a more in-depth explanation). Some 380,000 years after the Big Bang, light separated from matter and the liberated photons preserved a record of the mass density fluctuations from that early time, which is now seen as the cosmic microwave background (CMB).

By determining the musical signals produced by this cosmic "instrument" — its resonant frequency and overtones — astronomers can learn about the early universe's size, shape, and structure, as well as the physics of the plasma. They also can determine the relative amounts of ordinary (baryonic) matter to dark matter, because the primordial sound waves affect only ordinary matter.

Most work in cosmology involves moving backward — getting close to the moment when everything began. Today, investigators can detect temperature differences in the CMB as small as a millionth of a degree and measure the clumpiness of galaxies with growing precision.

From that evidence, they can elicit the "music" responsible for the pattern and, going further back in time, characterize the instrument that made the sounds. "It's like hearing a symphony and trying to figure out which instruments played what notes," explains Szalay. Except, he says, "in cosmology, the orchestra is much 'simpler,' with fewer instruments and fewer notes, but the piece takes a long time to play."

Understanding harmonics

To understand the cosmic symphony, astronomers face the mammoth task of making sense of reams of data. A statistical tool now widely used for evaluating cosmological data is a spin-off of the Szalay brothers' work in electronic music.

In the 1970s, they began building electronic equipment for their band. In so doing, Alex says, "I learned an enormous amount about signal processing, discovering new techniques for collecting and analyzing data I later brought into cosmology."

Andras has designed some of the most sophisticated digital pianos and synthesizers. Working on one invention in the early 1990s, Andras needed to reproduce electronically the entire range of sounds a piano can make at a time when digitally storing this much information (roughly a gigabyte, in all) was prohibitively expensive.

He discovered a statistical approach from decades prior called the Karhunen-Loève (K-L) technique that could solve his problem. Using this method, Andras could reduce all piano sounds to eight fundamental components, each with different amplitude settings. Data compression would decrease the information total from a gigabyte to a megabyte. He asked Alex what he thought.

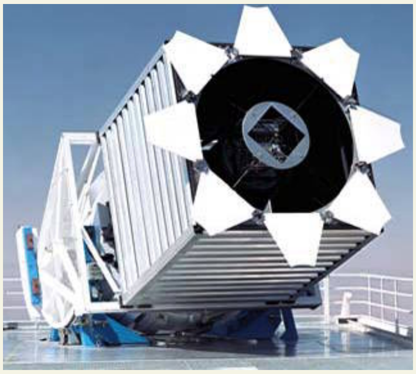
Alex was fascinated with the Karhunen-Loève algorithm and made suggestions Andras eventually incorporated in the first (and possibly only) musical synthesis device to use K-L. Months later, while discussing cosmology with Joseph Silk, Szalay realized K-L was what they needed to analyze the CMB and large-scale distribution of galaxies. "In electronic music, the point is to synthesize a desired waveform," he explains. "In cosmology, it's the other way around: You take the output waveform and try to determine the physical processes responsible for it. The same tools work, even though the direction is opposite."

/// SLOAN DIGITAL SKY SURVEY — EXTREME MAPPING

The Sloan Digital Sky Survey (SDSS) is the most ambitious astronomical sky survey ever. It is mapping one-quarter of the sky to cover 100 times the volume astronomers have explored so far. The project began collecting data in June 1998 and is scheduled to complete the survey this year, with the full data release scheduled for 2006, although participants hope to extend the survey through 2008.

From data collected in five filter bands — from infrared to ultraviolet — SDSS will measure the shape, brightness, and color of hundreds of millions of celestial objects. A spectrograph will be used to measure the distance to 1 million galaxies and 100,000 quasars.

The SDSS will allow astronomers to see the mass distribution in the early universe. It also will measure the "local distribution" of galaxies and compare near with far to see how galactic properties change with time. Because SDSS looks at such a wide field-of-view, it also will study Milky Way objects — the composition of old stars — and even asteroids in our solar system.



SDSS

THE SDSS 2.5-METER TELESCOPE is located at Apache Point Observatory in Sunspot, New Mexico. The telescope is able to take focused images of an area equal to 30 Full Moons.

And the best part? All images will be available via the Internet, so scientists can download data instead of spending months — sometimes years — in front of a telescope. SDSS will be the universal astronomical database, available to the science community and the public. — *Liz Kruesi*

COURTESY OF ALEX SZALAY

PANTA RHEI performing during one of its many concerts in the 1970s. Alex Szalay is the guitarist on the right, in plaid and bell-bottoms.

Karhunen-Loève is related to a statistical technique called Fourier analysis, which can break down a sound — or any curve on a graph — into a combination of sine waves of specific amplitude, frequency, phase, and orientation. In cosmology, the Fourier technique works best in a symmetrical volume like a cube, whereas K-L can identify fundamental modes in irregular volumes such as the "cells" used in the SDSS.

Statistical serenade

In the mid-1990s, Szalay teamed up with his then-postdoc Michael Vogeley — now

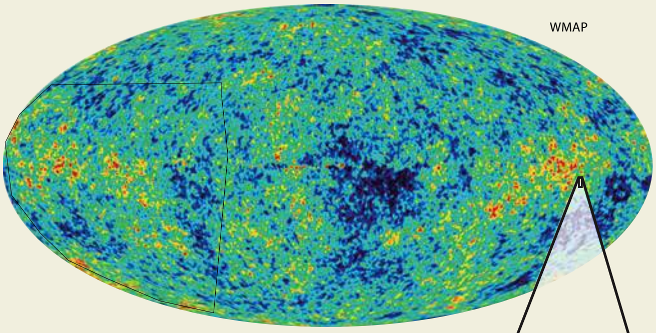
/// THE COSMIC SLINKY TOY AND THE CMB

In the early universe, light and matter were linked together in the form of plasma. Cosmologists believe small variations in the plasma's density were imprinted earlier during a period of rapid acceleration — inflation. The study of these fluctuations may help explain inflation.

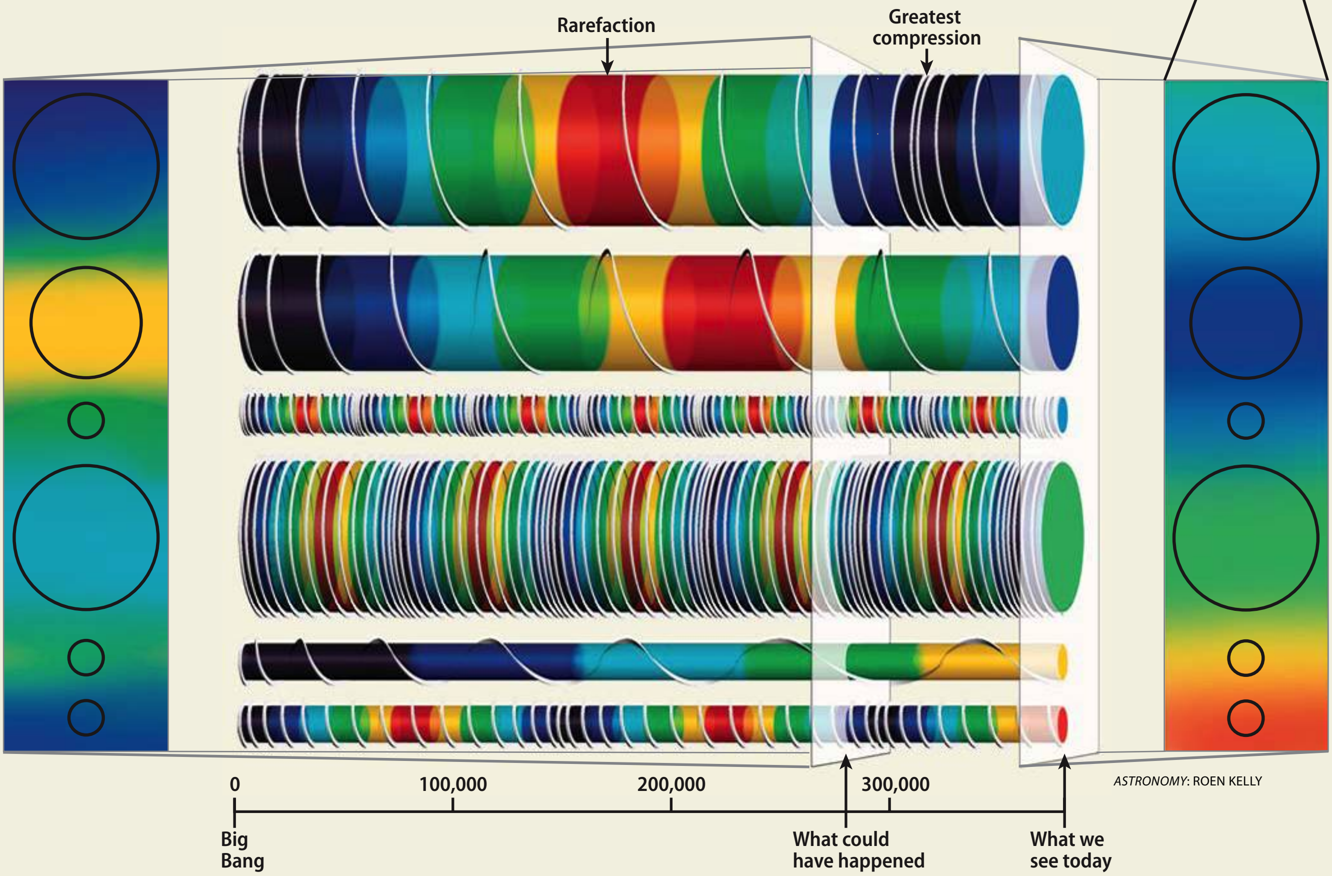
The fluctuations grew through gravitational collapse. Matter and light, linked together, collected in high-density regions, creating deeper gravitational pockets. In effect, the rich got richer, the poor got poorer.

The flow of plasma resembles standing sound waves, or acoustic oscillations. High-density areas are equivalent to compression regions. Low-density areas are like rarefaction regions. (Imagine pushing a Slinky forward periodically.) According to Stephan Meyer, a University of Chicago astrophysicist and a Wilkinson Microwave Anisotropy Probe (WMAP) team member, "acoustic oscillations are one of the things that happen to matter in the process of gravitational collapse."

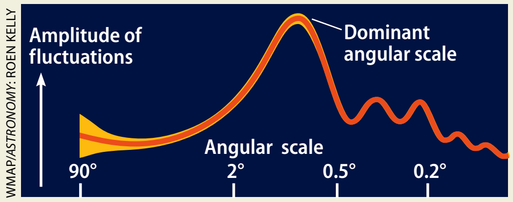
The fluctuation pattern in the early universe's plasma we see today as standing waves of different amplitudes and frequencies depends on what the universe's contents were when light almost instantly scattered from matter 380,000 years after the Big Bang. At this so-called "surface of last scattering," the acoustic and gravitational fluctuations left an imprint in the cosmic fluid. When light is emitted from a high-density area, it "climbs out" of that region. It thus loses energy, cools, and is redshifted (red splotches). As light "falls into" a high-density region, it gains energy, becomes hotter, and is blueshifted (blue splotches). — *L. K.*


WMAP

OSCILLATING SLINKY-LIKE TUBES move like sound waves. The CMB pattern depends on the moment of last scattering. This diagram shows two last-scattering options, each with random oscillation patterns, and varying amplitudes and frequencies. If light scattered from matter 100,000 years prior, we would see a different pattern in both the CMB and the universe's structure.

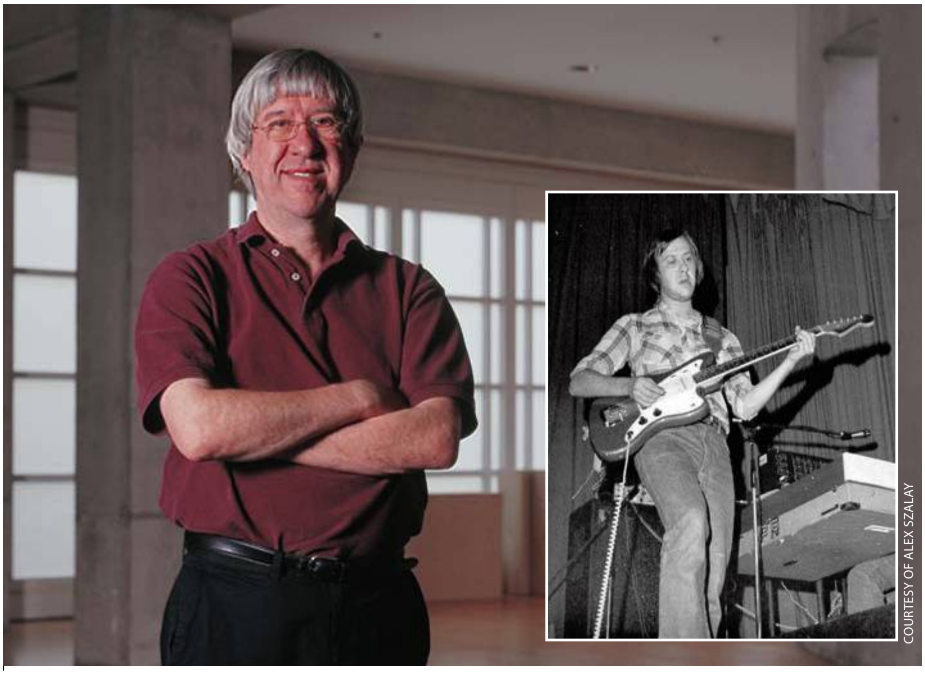


ASTRONOMY: ROEN KELLY



WMAP/*ASTRONOMY*: ROEN KELLY

SOUND WAVES FROM THE CMB. The color sky map above can be shown in a plot of the temperature fluctuation's amplitude as a function of its angular size. The flat area on the left corresponds to fluctuations from inflation that are so large they have not yet evolved. The peaks beginning at an angular scale of 1° are sound wave imprints. The largest peak corresponds to the angular scale that evolved into the dominant structure size we see today.



COURTESY OF ALEX SZALAY

KYLE BERGNER

ALEX SZALAY awaits his next project: the National Virtual Observatory. **INSET:** Alex Szalay rocks on the guitar while playing with Panta Rhei in the mid-1970s.

on the Drexel University faculty — to bring the idea to their colleagues. "It's the best possible approximation of Fourier analysis you can do with our data," Vogeley explains. For this reason, K-L is crucial to the SDSS analysis. That's a prominent role, given that SDSS is the largest galaxy survey ever undertaken (see "Sloan Digital Sky Survey" on page 49). After it's complete, SDSS will have measured the distance to more than 1 million galaxies and determined the positions and brightness of more than 100 million celestial objects. The process will generate over 40 terabytes (40 million megabytes) of information.

With this data, SDSS researchers will determine the "power spectrum," to reveal deviations in galactic density in different-size volumes and regions of space. Aided by K-L, they will convert their raw data into a set of fundamental modes — or waves — having set frequencies and amplitudes.

The power spectrum shows how amplitude varies with frequency, telling astronomers the physical scale or wavelength at which the biggest fluctuations occur. Szalay is interested in large-scale fluctuations only, on the order of 195 to 650 million light-years, because they contain information about the early universe, whereas small-scale fluctuations reflect individual galaxies. K-L acts as a filter, so investigators can select the cosmological scales and ignore the rest.

"It's like a pointillist painting," Vogeley says. "If you view it on a small scale, you'll just see individual dots and miss the big picture. But in cosmology, all we care about is the big picture." In preparing for SDSS, Vogeley and Szalay knew they had to match the quality of the data with that of the analysis. "We'd been doing space-age astronomy with stone-age statistics," says Vogeley.

In addition to SDSS, the K-L technique also is used in CMB experiments. The main benefit is data compression, says Massachusetts Institute of Technology cosmologist Max Tegmark: "It enables you to throw away the noise and keep everything you want." Tegmark credits Szalay and Vogeley with introducing the K-L tool to cosmology. But Szalay's contributions extend far beyond K-L modes, says Tegmark. "He has spearheaded the use of advanced statistics throughout astronomy and is interested in bringing to bear anything that will advance the field."

According to Dick Bond, a CMB expert, "Alex has been an unbelievably powerful force at SDSS, and after the full survey comes out, people will see what he's done. Data archiving is not some minor problem. It is *the* problem in astronomy today, and Alex is leading the way."

"The word 'interdisciplinary' is used a lot these days," says Vogeley, "but Alex is interdisciplinary by nature. That's what enabled him to recognize that the problems he had grappled with in music, signal processing, and cosmology were, in essence, the same problem."

More than a melody

Szalay's work as principal investigator for the National Virtual Observatory (NVO) is another example of his contributions to astronomy. The project's goal — to create a worldwide "telescope" to allow ready access to data in multiple wavelengths and from multiple instruments — is nothing short of transforming astronomy as we know it.

The challenge is to manage all the data now pouring in from surveys across the electromagnetic spectrum, while facilitating multi-spectral comparisons. If the NVO works as planned, says Szalay, "scientists will be free to concentrate on science, taking on projects that were not conceivable before, without getting mired in menial tasks," such as data organization.

An undertaking this big, combined with his efforts on the gargantuan SDSS, makes for a huge time commitment. After long days working on the forefront of astronomy, Szalay no longer has the time to spend his nights performing in rock clubs, though he often retires to his studio at home to play guitar and compose. He doesn't regret his career choice, yet occasionally can't help thinking about "the road not taken."

Recently, Szalay heard Brian May, lead guitarist for the rock group Queen, speaking on the radio about interstellar dust. Although this might seem incongruous, in the 1970s, while Szalay pursued his graduate work, May was a Ph.D. candidate in astrophysics at Imperial College in London, similarly torn between his studies and the lure of rock 'n' roll.

May left graduate school when his band hit the big time. He claims he wasn't disciplined enough to be a scholar, calling himself a better musician than astronomer. The world, May says, got the better choice.

"There's a guy who went the other way," Szalay notes. According to his colleagues, the world got "the better choice" when Szalay opted for academia over music. Thanks to his decision more than 2 decades ago, claims Bond, astronomy is stronger today.

But Szalay has not entirely put music on the sidelines: He spends every day trying to master the ultimate instrument — the universe itself.

ONLINE EXTRA Listen to Panta Rhei at www.astronomy.com/toc

BY MARTIN RATCLIFFE AND ALISTER LING

JULY 05

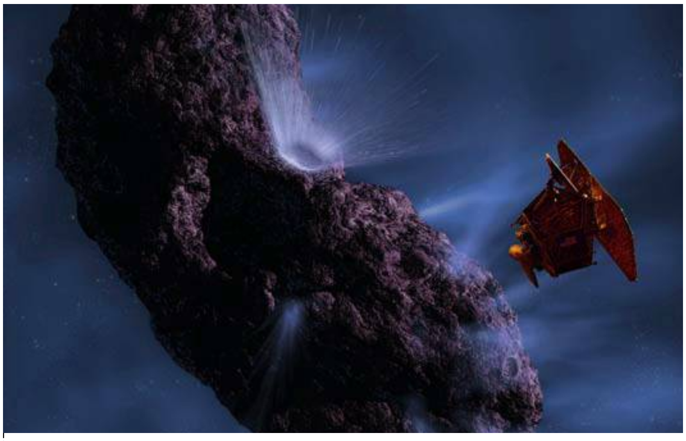
A comet impact puts an exclamation mark on a month that also features evening views of Jupiter gleaming in the southwest, and Venus and Mercury dancing in twilight.

A celestial fireworks display

The interplanetary space probe Deep Impact is set to blast a hole in Comet 9P/Tempel 1 July 4. In excavating a stadium-size crater, the probe will allow planetary scientists to analyze the composition of frozen material dating back to the solar system's formation. No one knows what effects the impact will have on the comet's appearance, but astronomers think there's a reasonable chance backyard observers far from city lights will see a change in the comet's dusty halo in the early morning of the 4th. Use the chart on page 61 to locate the comet, and log onto *www.astronomy.com* for observing tips and tricks.

A second periodic comet, 161P/Hartley-IRAS, glows low in the north. During their journeys across the sky, comets can draw our attention to interesting sights beyond our solar system. Don't miss Hartley-IRAS at the end of June when it skirts the Double Cluster in Perseus, a spectacular grouping of hundreds of stars.

The solar system's clockwork motion brings Saturn in line with the Sun this month, which prevents us from getting a good view. We'll have to wait until the latter half of August for it to return to the sky before dawn. On the other hand, gas-giant Jupiter remains a fine sight after sunset in the southwest. Look for a bright, steady beacon about one-third of the way up the sky. The earlier in the evening you observe it, the better your chances to spot cloud features called barges and festoons.



NASA/PAT RAWLINGS

NASA BLOWS A HOLE in Comet 9P/Tempel 1 the morning of July 4. With some luck, observers on Earth may see the comet brighten.

Use your binoculars to follow the extended dance between Venus and Mercury. Lurking low in the west-northwest about 45 minutes after sunset, the two planets appear side-by-side July 1. Venus shines brighter, appearing somewhat yellowed by our atmosphere. Mercury shows as a fainter dot to Venus' left. During the next 2 weeks, the innermost planet drops back toward the Sun gradually, fading from view after midmonth. A pale crescent Moon joins the pair the evening of July 8. A wide-field telescope at its lowest power will show the inner planets in the same field of view during July's first week.

During the evening hours, many will assume the beacon in the west-northwest is an aircraft's landing light. This brilliant planet inspired humanity to create the poetry and mythology of Venus long before written words graced a page.

From the Southern Hemisphere, Venus and Mercury make a spectacular sight in a darkened sky. The view's much better from down south because the line from the Sun to the planets stands almost straight up compared with the shallow angle it makes for northerners.

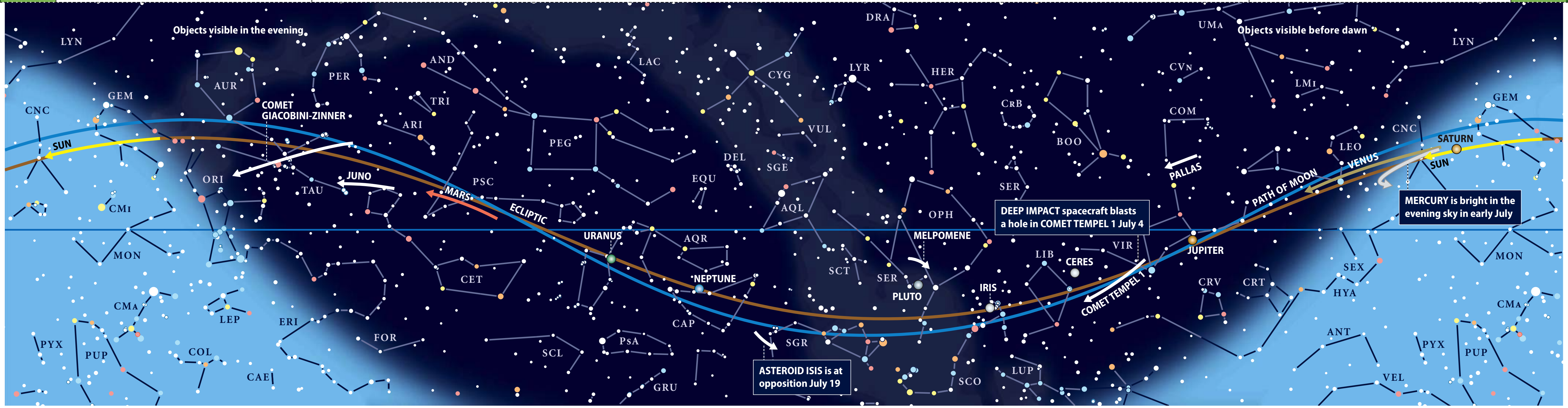
Longer days and steeper rays of sunlight make this the summer season for the Northern Hemisphere. It surprises many people to learn Earth actually lies at its farthest point from the Sun July 4/5. The egg shape of Earth's orbital ellipse is so slight, however, your eyes couldn't tell the difference from a perfect circle without seeing one next to the other.

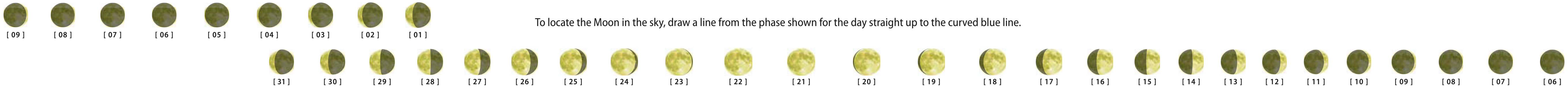
The Moon's orbit around Earth deviates from a circle much more than Earth's orbit around the Sun. When the Moon reaches its full phase July 21, it will be near its second-closest approach to Earth of 2005, bringing exceptionally high and low tides to coastal areas. Compare this Full Moon with images from last December or next February, and you'll see how much bigger it appears now.

Combine this bigger Moon with the "Moon illusion" — our satellite's tendency to loom larger when it lies near the horizon — and it will seem huge as it rises July 21. You can make it shrink by sighting the Moon through a cardboard tube. The Moon illusion is so complex entire books have been written on it.

Planets this month

This map unfolds the entire night sky from sunset (at right) until sunrise (at left). Arrows and colored dots show motions and locations of solar system objects during the month.


Objects visible in the evening
Objects visible before dawn
LYN
CNC
GEM
AUR
PER
AND
TRI
ARI
LAC
CYG
DRA
LYR
HER
UMA
CVN
COM
LMI
LYN
GEM
CNC
LEO
SUN
SUN
COMET GIACOBINI-ZINNER
ORI
TAU
JUNO
MARS
PSC
ECLIPTIC
PEG
DEL
SGE
VUL
EQU
AQL
CRB
BOO
SER
OPH
PALLAS
PATH OF MOON
VENUS
SATURN
MERCURY is bright in the evening sky in early July
CMI
MON
CMA
LEP
ERI
COL
PYX
PUP
CAE
FOR
CET
SCL
PSA
GRU
URANUS
AQR
NEPTUNE
CAP
SGR
ASTEROID ISIS is at opposition July 19
SCT
SER
PLUTO
MELPOMENE
DEEP IMPACT spacecraft blasts a hole in COMET TEMPEL 1 July 4
IRIS
LIB
CERES
VIR
COMET TEMPEL 1
JUPITER
CRV
CRT
SEX
HYA
MON
CMA
PYX
PUP
ANT
VEL
SCO
LUP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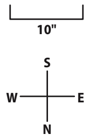
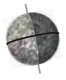
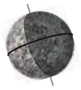
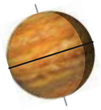
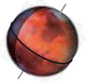
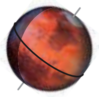
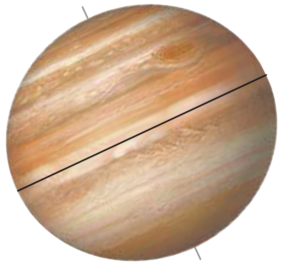
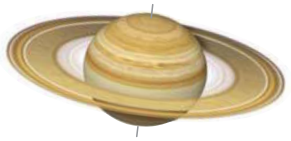
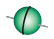
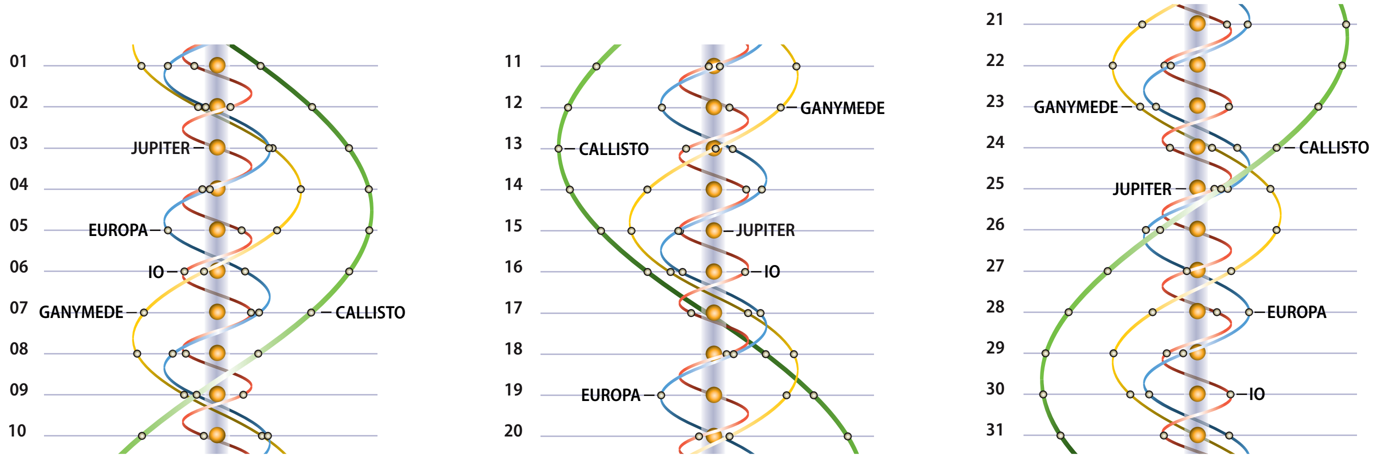
To locate the Moon in the sky, draw a line from the phase shown for the day straight up to the curved blue line.



PLANETS	 MERCURY	 MERCURY	 VENUS	 MARS	 MARS	 JUPITER	 SATURN	 URANUS	NEPTUNE	PLUTO
Date	July 1	July 15	July 15	July 1	July 31	July 15	July 1	July 15	July 15	July 15
Magnitude	0.1	0.7	–3.7	–0.1	–0.5	–1.9	0.2	5.8	7.8	13.8
Angular size	6.9"	8.9"	11.6"	9.3"	11.2"	35.4"	16.6"	3.6"	2.3"	0.1"
Illumination	55%	32%	88%	84%	84%	99%	100%	100%	100%	100%
Distance (AU) from Earth	0.970	0.753	1.443	1.004	0.834	5.565	10.036	19.371	29.132	30.103
Distance (AU) from Sun	0.427	0.465	0.720	1.383	1.383	5.455	9.079	20.068	30.062	30.977
Right ascension (2000.0)	8h25.8m	9h19.1m	9h32.7m	0h51.1m	2h01.4m	12h42.8m	8h00.4m	22h48.6m	21h17.1m	17h28.6m
Declination (2000.0)	20°21'	14°02'	16°18'	2°44'	9°24'	–3°14'	20°49'	–8°26'	–15°56'	–15°01'

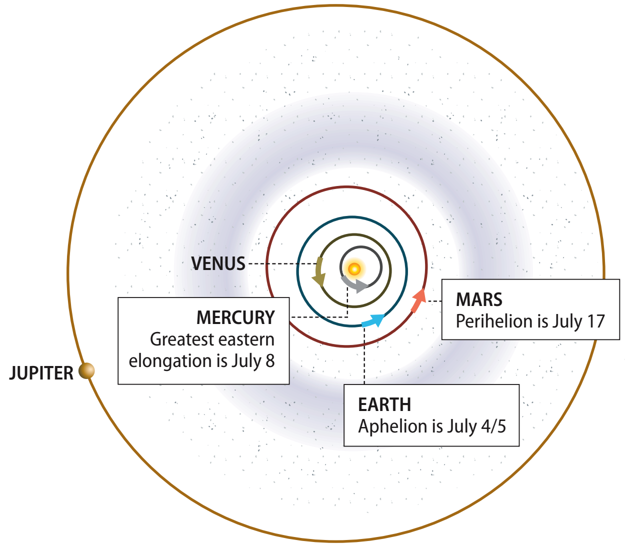
Jupiter's moons

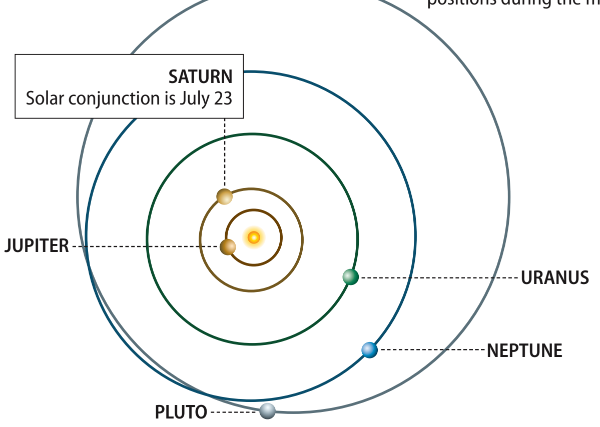
Dots display positions of Galilean satellites at 11 P.M. EDT on date shown. South is at top to match the view through a telescope.



The planets in their orbits

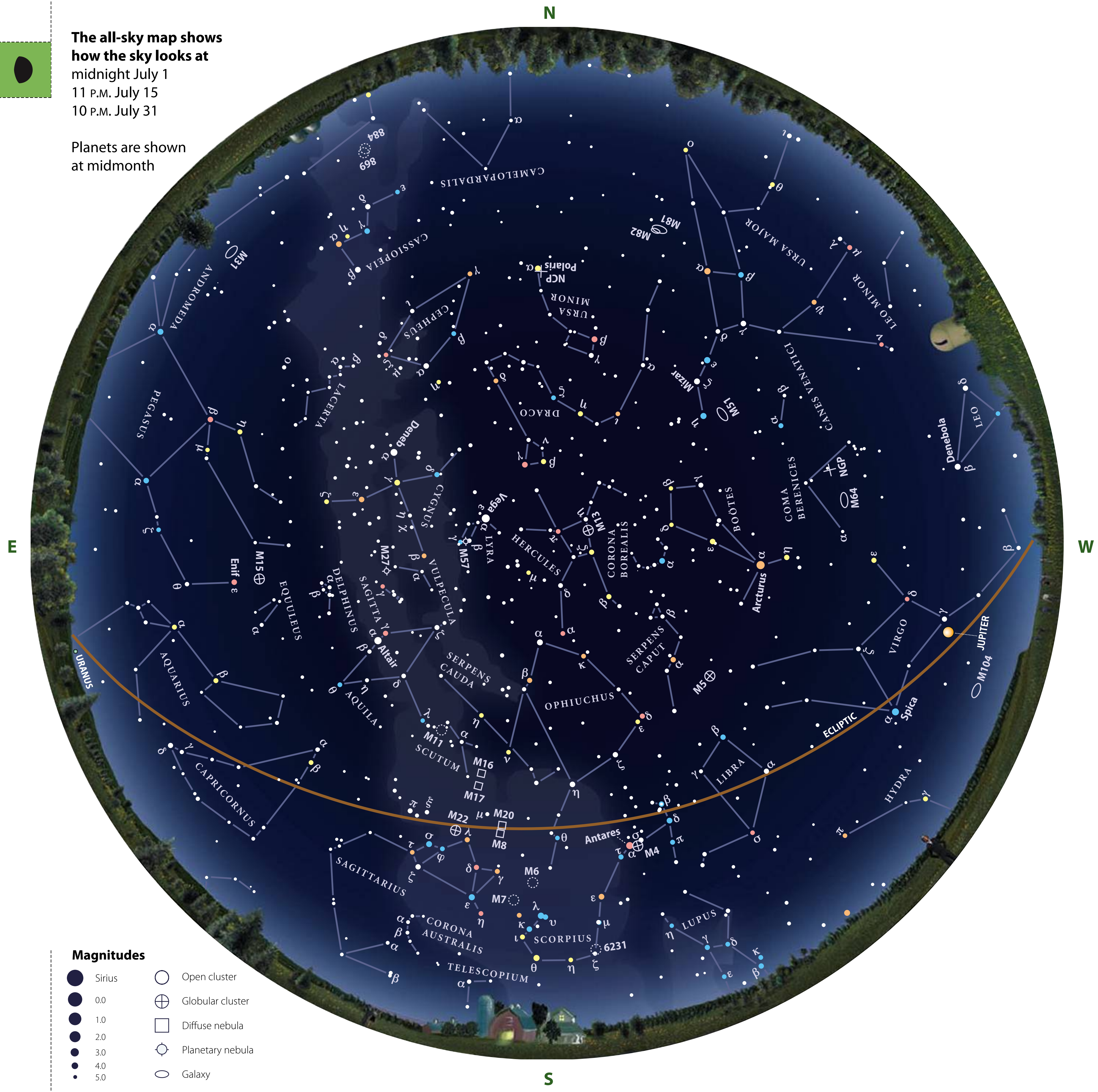
Arrows and dots show planets' positions during the month.


VENUS
MERCURY
Greatest eastern elongation is July 8
MARS
Perihelion is July 17
EARTH
Aphelion is July 4/5
JUPITER


SATURN
Solar conjunction is July 23
JUPITER
URANUS
NEPTUNE
PLUTO

The all-sky map shows how the sky looks at
midnight July 1
11 P.M. July 15
10 P.M. July 31

Planets are shown
at midmonth


N
E
W
S
CAMELOPARDALIS
884
698
CASSIOPEIA
M31
ANDROMEDA
NCP
Polaris
URSA MINOR
M81
M82
URSA MAJOR
LEO MINOR
CEPHEUS
LACERTA
PEGASUS
DRACO
Mizar
M51
CANES VENATICI
LEO
Denebola
Deneb
CYGNUS
Vega
LYRA
M57
HERCULES
M13
CORONA BOREALIS
BOÖTES
COMA BERENICES
NGP
M64
Arcturus
M27
VULPECULA
SAGITTA
DELPHINUS
EQUULEUS
Enif
M15
Altair
AQUILA
SERPENS CAUDA
SERPENS CAPUT
M5
OPHIUCHUS
VIRGO
JUPITER
M104
Spica
ECLIPTIC
URANUS
AQUARIUS
CAPRICORNUS
M11
SCUTUM
M16
M17
M22
M20
M8
LIBRA
HYDRA
Antares
M4
M6
M7
SAGITTARIUS
CORONA AUSTRALIS
SCORPIUS
6231
LUPUS
TELESCOPIUM

Magnitudes

●	Sirius
●	0.0
●	1.0
●	2.0
•	3.0
•	4.0
·	5.0

○	Open cluster
⊕	Globular cluster
☐	Diffuse nebula
⌖	Planetary nebula
⬭	Galaxy

This map portrays the sky as seen near 35° north latitude at times shown in the upper left corner of the page. Located just outside the map are the four directions: north, south, east, and west. To find stars above your horizon, hold the map overhead and orient it so a direction label matches the direction you're facing. The stars above the map's horizon now match what's in the sky.

july 05

SUN.	MON.	TUES.	WED.	THURS.	FRI.	SAT.
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[24]	[25]	[26]	[27]	[28]	[29]	[30]
[31]						

05 Earth is at aphelion (94.5 million miles from the Sun), 1 A.M. EDT

06 New Moon is at 8:02 A.M. EDT

07 Mercury passes 1.6° south of Venus, 4 A.M. EDT

08 The Moon is at apogee (252,502 miles from Earth), 1:39 P.M. EDT

The Moon passes 5° north of Mercury, 2 P.M. EDT

The Moon passes 3° north of Venus, 3 P.M. EDT

Mercury is at greatest eastern elongation (26°), 11 P.M. EDT

13 The Moon passes 0.8° south of Jupiter, 2 P.M. EDT

14 First Quarter Moon is at 11:20 A.M. EDT

17 Mars is at perihelion (128.4 million miles from the Sun), noon EDT

The Moon passes 0.6° north of Antares, midnight EDT

21 Full Moon is at 7:00 A.M. EDT

The Moon is at perigee (221,928 miles from Earth), 3:44 P.M. EDT

22 Venus passes 1.2° north of Regulus, 11 A.M. EDT

23 Saturn is in conjunction with the Sun, 1 P.M. EDT

27 The Moon passes 4° north of Mars, 4 P.M. EDT

Southern Delta Aquarid meteor shower peaks

Last Quarter Moon is at 11:19 P.M. EDT

ONLINE EXTRA For a definition of terms, visit www.astronomy.com/glossary

THE DEEP SKY

As springtime's galaxy glory gives way to summer's globular cluster craziness, the asteroid Pallas cruises the shallow sky nearby.

Doubling up

Although the small constellation Coma Berenices doesn't look like much to the naked eye, it packs a full complement of splendid deep-sky objects. Two months ago, we focused on the constellation's northern end. This month, we tackle the Blackeye Galaxy, a pair of globular clusters, and some double stars on the southern side.

A 4° hop west from Alpha (α) Comae Berenices will land you on 32 Com, a wide pair of whitish stars glowing at magnitudes 6.3 and 6.9. Observations show the two are unrelated — the fainter star lies about 1,400 light-years closer to Earth.

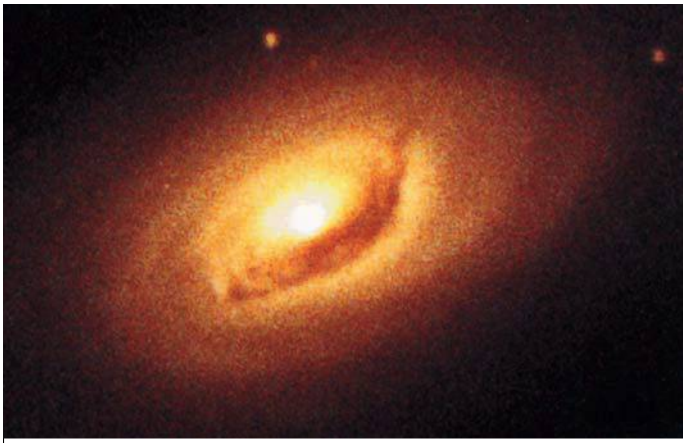
Martin Ratcliffe *is former president of the International Planetarium Society.* **Alister Ling** *is a meteorologist for Environment Canada.*

From July 13 to 15, asteroid Pallas shares a medium-power field with 32 Com. Pallas traces a path just north of the stellar pair. The asteroid glows at magnitude 9.5, less than one-tenth as bright as the stars.

Sweep 4° due north of 32 Com and you'll land on a true binary star, 35 Com. This system's stars orbit each other with a period of 510 years. Just 1" separates the two, putting them near the limit for a 5-inch telescope under steady skies. You'll need a magnification of at least 250x to split them. The 5th-magnitude primary lies north of the companion and outshines it by 2 magnitudes.

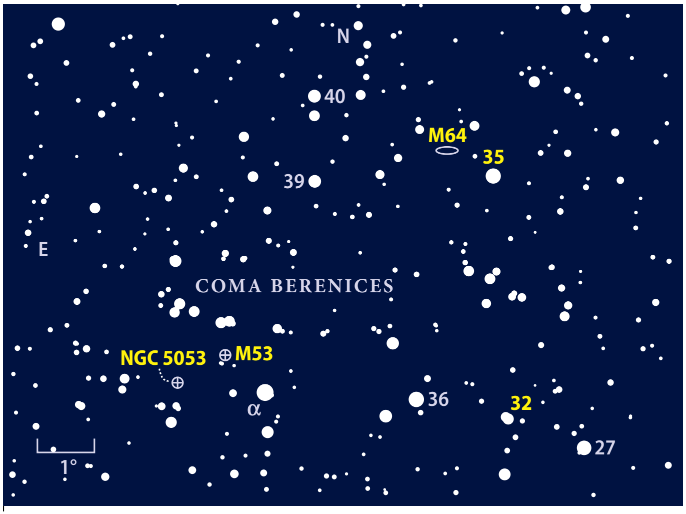
A glowing shiner

You can use 35 Com as a springboard into the depths of space. The Blackeye Galaxy (M64) lies 0.9° east-northeast of the binary system. German astronomer Johann Bode discovered the object in 1779, beating his contemporary, Charles Messier, to the punch. Glowing at 9th magnitude with a size of 13', the galaxy appears as a reasonably bright oval surrounding a pinpoint core. It gets its nickname from a huge swath of obscuring dust on its northern side. If you're new to observing, the dark patch may not be visible right away. With practice, the patch shows up through a 6-inch scope.



JASON WARE

THE BLACKEYE GALAXY (M64) gets its name from a band of dust that obscures most starlight along the galaxy's northern side.



ASTRONOMY: ROEN KELLY

COMA BERENICES offers deep-sky observers with small scopes a nice mix of galaxies, star clusters, and double stars.

Granular globulars

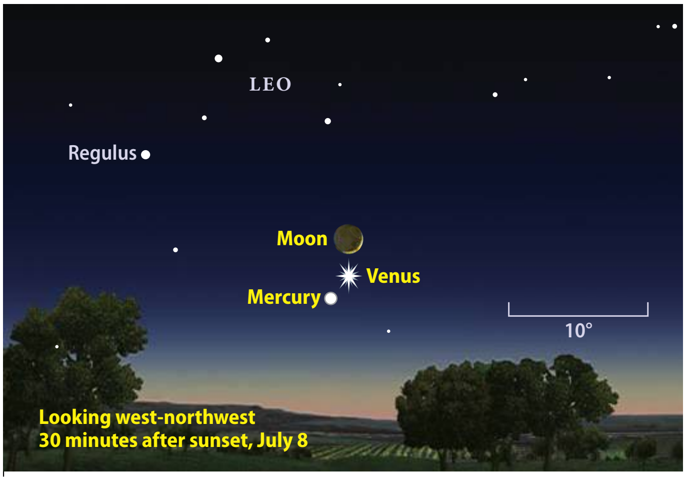
Some of the universe's oldest objects are globular clusters — dense stellar spheres typically containing several hundred thousand stars. We see more this time of year because they orbit the Milky Way's center, which lies in the summer constellation Sagittarius. It's a perspective effect that comes from our vantage in the "galactic suburbs." Coma Berenices provides a rare treat by having two globulars in one low-power field so far from "downtown."

One degree northeast of Alpha Com lies M53. Although it, too, was first seen by Bode, Messier's catalog has stood the test of time. This 7.5-magnitude globular appears as a fuzzy "star" through binoculars, and shows up nicely in a small scope. If the air is steady, crank the power past 200x and look for individual stars. The brightest glow at 14th magnitude, so you'll need a 6-inch scope to detect the glimmers. M53 lies 58,000 light-years from Earth.

Just 1° southeast of M53 is the second cluster, NGC 5053. Although it lies some 5,000 light-years closer to us, it appears smaller and fainter. If you can resolve M53 into individual stars, then NGC 5053 will sparkle subtly as well.

THE PLANETS

Although you have the chance to view every planet this month, only Jupiter (blazing in the evening sky) and Mars (prominent after midnight) will take your breath away.



ASTRONOMY: ROEN KELLY

A SLENDER CRESCENT MOON lies just above Mercury and Venus in evening twilight July 8.

Mercury and **Venus** remain neighbors in the gathering twilight during the first 2 weeks of July, although they aren't as close as they were in late June. Venus gleams nearly 40 times brighter and will be a cinch to see in bright twilight. Mercury has started to fade and will require more patience to locate.

Mercury reaches greatest elongation July 8, when it lies 26° east of the Sun. Coincidentally, that evening a 6-percent-lit crescent Moon passes 3° north of Venus. As the trio slips toward the horizon, those with a clear western sky might spot the Beehive star cluster (M44) nearby, although twilight may have the upper hand.

Venus sits in front of the cluster's center July 3, but again twilight will interfere. On July 22, Venus stands 1° above 1st-magnitude Regulus, Leo the Lion's brightest star.

You might glimpse **Saturn** July 1, before it succumbs to twilight. The planet sets 1 hour after the Sun, and falls from view after July's first week. Saturn lies behind the Sun as seen from Earth at solar conjunction July 23. In late August, the planet reappears before dawn.

Brilliant **Jupiter** dominates the southwestern evening sky. The giant planet shines at magnitude –1.9 in mid-July, making it the brightest point of light in the sky after Venus sets. Through a telescope, Jupiter appears 35" across its equator but only 33" from pole to pole. The difference gives the planet a squashed appearance. The most obvious features on Jupiter are two dark cloud belts running parallel to the equator.

As July opens, Jupiter stands 1.5° below Gamma (γ) Virginis, Virgo's second-brightest star. During the next 2 months, watch every clear night as Jupiter sinks toward the horizon and Venus rises to meet it. Their motion sets the stage for a conjunction of the two brightest planets in early September.

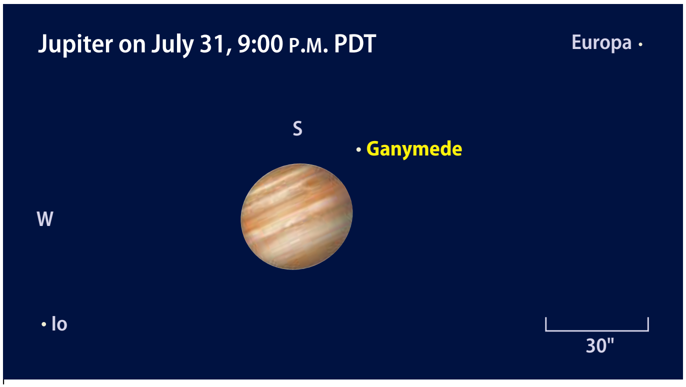
On the evening of July 13, a crescent Moon lies 5° from Jupiter. On the same date, during daylight, observers in the southern half of South America and the Falkland Islands will see the Moon occult Jupiter.

This month, Jupiter reaches a positional milestone: An imaginary line from the Sun to Earth to Jupiter forms a right angle. This configuration is called quadrature, and Jupiter reaches it July 1.

Why should this interest us? The geometry means that from our vantage point, Jupiter's shadow extends as far east of the planet as possible. So, as the Galilean moons orbit Jupiter, we see them enter or leave the shadow farther from the planet's limb than at other times.

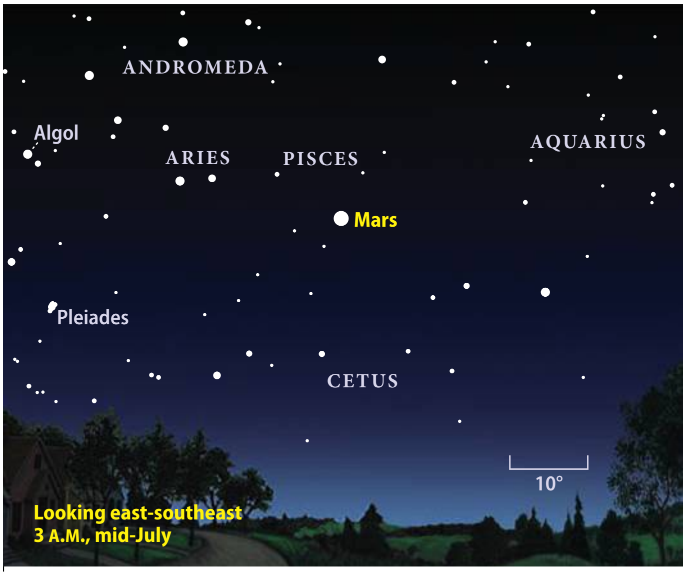
Here's how a typical sequence plays out for Ganymede: As Ganymede heads behind Jupiter, the planet's western limb blocks the moon from view. A few hours later, Ganymede reappears at Jupiter's eastern limb. A couple of hours after that, Ganymede disappears as it enters Jupiter's shadow. Ganymede takes another few hours to traverse the shadow, then returns to full brightness as the eclipse ends.

Part of this sequence can be viewed the evening of July 31. Ganymede reappears from behind Jupiter's limb at 10:37 P.M. EDT and enters Jupiter's shadow 124 minutes later. Eastern North America gets the best view of the first event, while the West Coast sees the second event (at 9:41 P.M. PDT). Callisto can exhibit similar sequences, although not at this point in Jupiter's orbital year. Io and Europa lie too close to Jupiter for either occultation reappearance or eclipse disappearance to be seen.



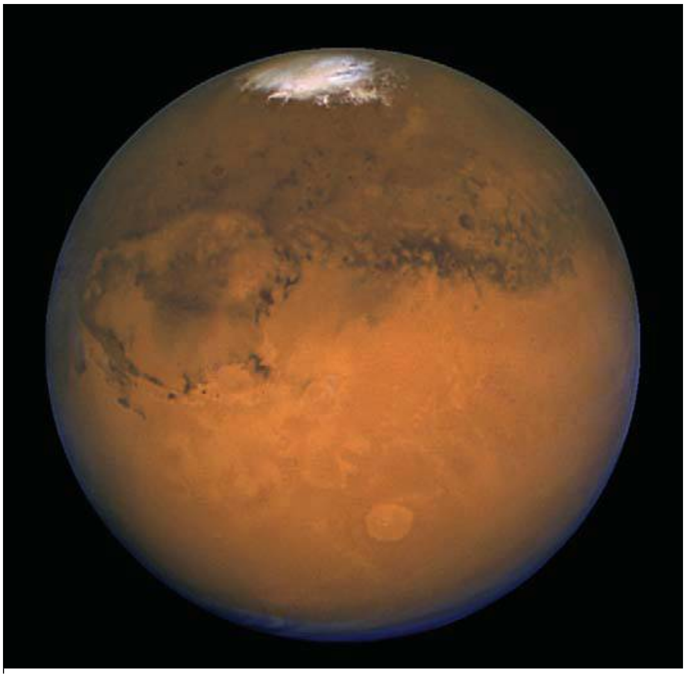
ASTRONOMY: ROEN KELLY

GANYMEDE EMERGES from behind Jupiter's eastern limb July 31 and then, within a few hours, disappears into the planet's shadow.



ASTRONOMY: ROEN KELLY

MARS COMES TO PROMINENCE in July as it brightens past magnitude 0.0 and its disk crosses the 10"-diameter threshold.



NASA, J. BELL (CORNELL UNIVERSITY), AND M. WOLFF (SSI)

MARS' SOUTH POLAR CAP (at top) appears prominent through backyard scopes because it now tips in our direction.

After Jupiter sets, three distant planets take center stage. Uranus, Neptune, and Pluto present challenges for a variety of equipment. First up is Pluto, the hardest to see, followed by Neptune, and finally Uranus, an easy binocular target.

Pluto lies in Serpens Cauda, near the 3.5-magnitude star Xi (ξ) Serpentis. Pluto begins July 1.9° west of Xi, a distance that increases to 2.4° by month's end. You'll need at least an 8-inch telescope to spot the 13.8-magnitude planet. Search for Pluto under a dark, moonless sky. Your best chance comes when Pluto lies high in the south, between approximately 10 P.M. and midnight local daylight time, and during the first half of July before the Moon's phase grows too large.

Following the challenge of detecting Pluto, finding **Neptune** will be a breeze. Glowing at magnitude 7.8 among the stars of Capricornus, Neptune can be glimpsed through binoculars, and a telescope makes the task easy. The planet lies midway between Iota (ι) and 29 Capricorni in early July. Neptune's motion carries it westward until it lies 0.9° due south of 29 Cap at month's end. Neptune will reach opposition early next month, when it will be closest to Earth for the year, 2.7 billion miles away. Through a telescope this month, Neptune appears 2.3" across and sports a blue-gray hue.

Lying about 930 million miles closer to us than Neptune, **Uranus** appears brighter and bigger. At magnitude 5.8, Uranus glows bright enough to see with the naked eye from a dark site and is within easy range of binoculars. Its blue-green disk spans 3.6", nearly 60-percent larger than Neptune's. It shows up easily through a small telescope at moderate magnification. To find Uranus, first locate the 3.7-magnitude star Lambda (λ) Aquarii and place it about one-third of the way from the center toward the left edge of your binoculars' field of view. Uranus will be the brightest object near the center of the field. When July opens, only 1° (two Moon-widths) separates the star and planet, a distance that nearly doubles by the end of the month.

The final planet to appear rises in the east around midnight, just as Jupiter prepares to set in the west. **Mars** shines at magnitude –0.2 in mid-July, making it the brightest point of light in the morning sky. The best views come when it appears highest in the sky just before dawn.

On July 17, Mars makes its closest approach to the Sun, called perihelion. It then lies 128.4 million miles from our star and 84.5 million miles from Earth. This distance makes the Red Planet appear 10" across, a size large enough for small-scope owners to discern a reasonable number of features.

Mars also is approaching its winter solstice, which occurs in August. Like on Earth, Mars' northern hemisphere experiences winter near perihelion.

This observing season, Mars' south polar region tilts toward Earth, so observers can watch the south polar ice cap diminish. It's the larger of Mars' two polar caps and takes a long time to succumb to the Sun's warmth. Later in the season, as the ice cap thins, small scopes may show major rifts in the cap.

Through a telescope, Mars shows a noticeable gibbous disk. The planet appears 84-percent lit in July, its minimum phase for 2005. By November, when Mars reaches opposition, we'll see a fully illuminated face. Mars' size and phase will grow significantly during the next few months.

METEORS AND MOONS

Following a quiet June, near-Earth space gets more crowded with dust particles this month. The result: more meteors visible on balmy summer nights.

Perseid prelude

The best-known annual meteor shower, the Perseids, begins in mid-July. That's when Earth's orbit carries us into the fringe of the debris stream left by Comet 109P/Swift-Tuttle during its many orbits around the Sun. Activity begins slowly, with peak action reserved for August.

Another shower active this month is the Delta Aquarids. This shower has two main radiants, and the southern one peaks the night of July 27/28. Typical rates fall below 20 meteors per hour. Observers at more southerly latitudes get the better view because they see the host constellation Aquarius higher in the sky. Delta Aquarid meteors tend to be faint, and a Last Quarter Moon will adversely affect the view this year.

An even less productive shower, the Alpha Capricornids, produces only about 1 to 4 meteors per hour. The shower peaks July 30, but is active for most of July and the first half of August. Even better: The Moon appears as a waning crescent around the predicted maximum, so it won't interfere much with observations. Shower members have a distinctive slow speed and occasionally produce a bright fireball.

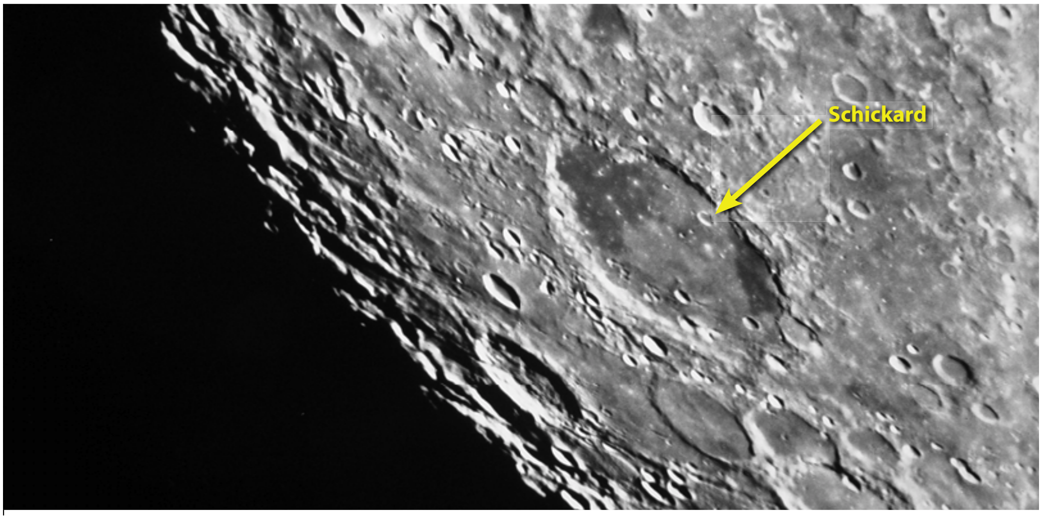
/// ANTARES OCCULTATION (JULY 17/18)

City	Disappearance	Reappearance
Houston	11:22 P.M. CDT	11:54 P.M. CDT
Los Angeles	8:14 P.M. PDT	9:09 P.M. PDT
Miami	12:46 A.M. EDT	1:43 A.M. EDT
New Orleans	11:35 P.M. CDT	12:06 A.M. CDT
Phoenix	8:32 P.M. MST	9:16 P.M. MST
San Diego	8:15 P.M. PDT	9:12 P.M. PDT

Flood of lava

Near the Moon's southwestern limb, a large flooded plain called Schickard dominates the scene. The crater's floor appears dark except for a lighter region stretching from the southwestern to northeastern wall and a bright triangular area near the center. The Sun rises over the crater shortly before Full Moon, and the subtle shadings become more prominent under stronger lighting.

Look for the cluster of a dozen craterlets at the floor's northern end. Also note the many craters superimposed on Schickard's wall, best seen when partially filled with shadow shortly after the Sun rises over the crater. The crater measures 141 miles across and appears elongated because of the foreshortening effect near the lunar limb. The low walls emphasize the massive flooding by lava that occurred early in the Moon's history, which stopped shortly before obliterating the crater walls.



FROM CONSOLIDATED LUNAR ATLAS (LPL/UA)

LUNAR CRATER SCHICKARD appears foreshortened (wider in the north-south direction than east-west) because it lies near the Moon's southwestern limb.

Moon slays Antares

On the night of July 17/18, the Moon blocks Antares (Scorpius' brightest star) from view for observers in the western and southern United States. Regions to the north will see the Moon glide below the bright orange-red star. Along a narrow track stretching from the Northwest across the country to Florida, people will witness a grazing occultation. During these exciting events, observers can watch Antares disappear and reappear multiple times as it peeks out from behind the mountainous regions along the Moon's limb. For occultation times for representative cities, see the table above.

COMETS AND ASTEROIDS

You'll want to view Comet 9P/Tempel 1 as NASA's Deep Impact spacecraft crashes into it, but don't forget to check out another nice comet, 161P/Hartley-IRAS.

Crash course

In the wee hours of July 4, Comet 9P/Tempel 1 gets slammed by an 816-pound projectile as part of NASA's Deep Impact mission. Scientists hope to learn more about Tempel 1's interior and, by extension, all such primordial balls of dirty ice. The collision could create an expanding cloud of dust and perhaps a new jet. If you observe from a dark location and have a little luck, you'll see a fresh spray of material. Use the finder chart to zero in on the comet. See "Fireworks on the Fourth" in the June issue for more details on this unique event.

Practice your comet-observing skills on a brighter object, 161P/Hartley-IRAS. Glowing at 9th magnitude, this periodic visitor is making its first return to the inner solar system since Malcolm Hartley and the Infrared Astronomical Satellite (IRAS) discovered it in 1983. Scientists designed IRAS to look for warm dust. Because comets are shrouded in warm dust, IRAS discovered many during its short life.

Mark your calendar for the night of June 29/30, when the comet sails past the delightful Double Cluster in Perseus low in the north. The best views come during late evening hours before the Moon rises and spreads unwanted light across the sky. Observing conditions improve during the next few nights as the Moon wanes and rises later. Wide-field images of this region will reveal many other open star clusters and several large emission nebulae. The yellow-white glow from Hartley-IRAS will make an interesting addition.

By the end of July, when the Moon has left the evening sky again, the comet will lie about halfway between Polaris and the Big Dipper.

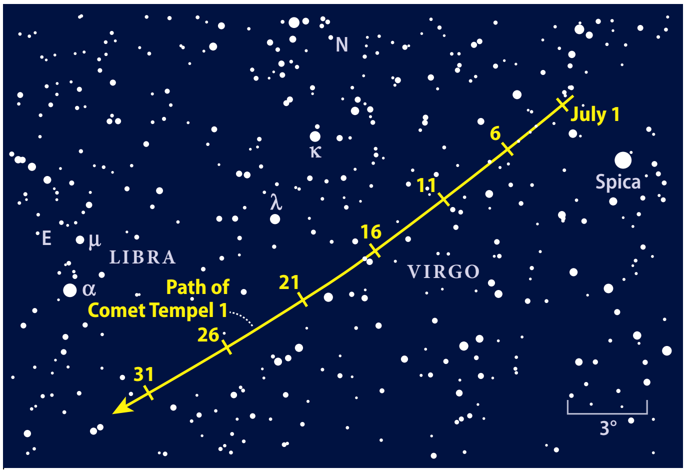
If you stay up all night during the New Moon weekend of July 1 and 2, have a predawn peek at Comet 21P/Giacobini-Zinner. You'll find the 10th-magnitude comet just west of the Pleiades star cluster (M45). Some returns of Giacobini-Zinner produce outbursts of the Draconid meteor shower in October. This time, scientists predict only a small increase above normal hourly rates.

Ceres tips the scales

Halfway between blue-white Spica and orange-red Antares, two luminaries in July's southern sky, lies Zubenelgenubi (Alpha [α] Librae). At magnitude 2.6, "Zu" joins Beta (β) Lib as the brightest stars in Libra. Observers find this double star most striking through binoculars because the components lie far apart.

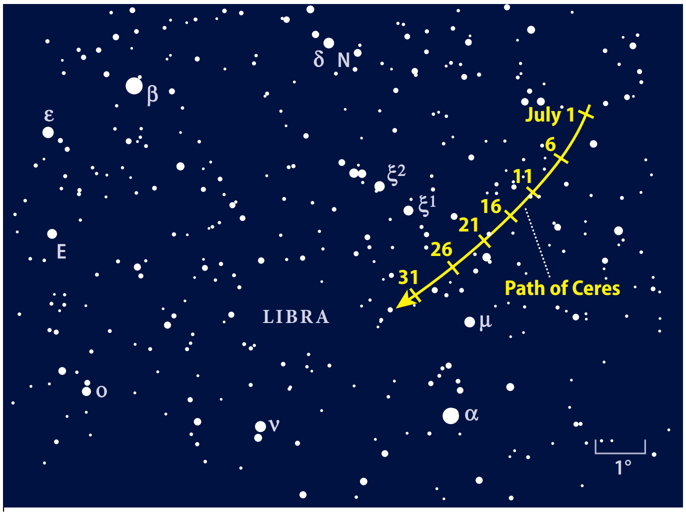
Trek a few degrees north of Zubenelgenubi to start hunting for 1 Ceres. The 8th-magnitude asteroid, the first to be discovered (back in 1801), is bright enough to see with binoculars, but a telescope would be the better bet. Background stars crowd the field as Ceres moves closer to the Milky Way, so identifying the rock will be tougher than usual.

The tried-and-true method is to detect its motion from one night to the next. Find Ceres' approximate location and make a quick sketch of the star field. Don't rely on a verbal description — it's too easy to mess up. Simply come back a night or two later and compare the field with your sketch to see which dot moved. That is Ceres. ◼



ASTRONOMY: ROEN KELLY

COMET 9P/TEMPEL 1 will be cruising near Spica July 4, when a projectile from the Deep Impact spacecraft will crash into it.



ASTRONOMY: ROEN KELLY

ASTEROID CERES glides through a star-rich region north of Alpha (α) Librae, but you should be able to spot it through a small scope.

Cassini's first close look at Enceladus shows Titan isn't the only Saturn moon with an atmosphere. /// BY RICHARD TALCOTT

An ice moon revealed

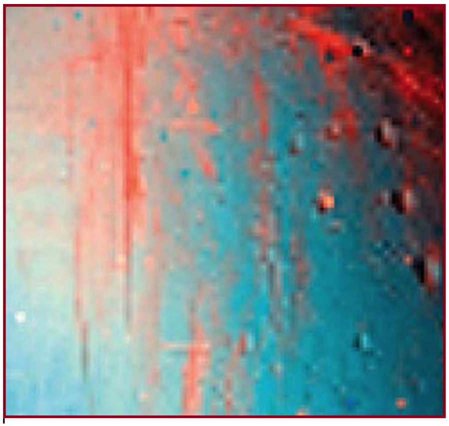
Planetary scientists expected discoveries when NASA's Cassini spacecraft swooped past Saturn's moon Enceladus in February and March. But even they were surprised to find a significant atmosphere enveloping the small (318-mile-wide) moon. The object's weak gravity can't retain gases, so Enceladus must constantly regenerate its atmosphere.

Although Cassini's camera didn't see any erupting ice volcanoes or geysers, it did find evidence of recent geological activity. Images of Enceladus' surface show a twisted network of ridges and troughs in some areas, complex fractures crisscrossing others, and entire regions nearly devoid of impact craters. All of these features suggest some internal process has resurfaced vast swaths of the moon's face. And where there's internal activity, escaping gases usually follow.

Enceladus (pronounced en-SELL-uh-duss) long has intrigued planetary scientists. The icy moon reflects nearly 100 percent of the sunlight that reaches it — so much that freshly fallen snow on Earth looks a little dingy in comparison — making Enceladus the solar system's most reflective body. The bright surface keeps Enceladus colder than any other saturnian moon, with noontime temperatures never rising above –325° Fahrenheit (–198° Celsius).

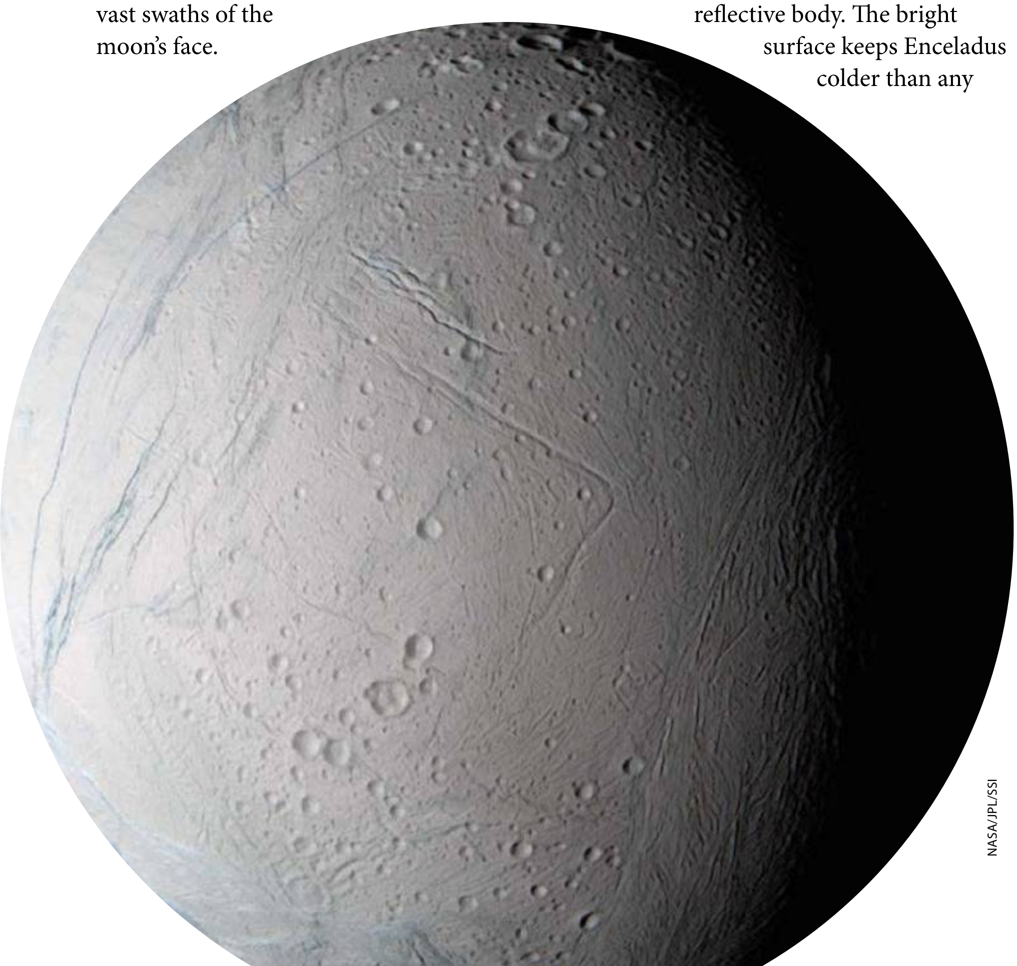
Images from the twin Voyager spacecraft in the early 1980s showed major chunks of the moon's surface have few craters and little topographic relief. Dubbed "smooth plains," these regions also indicate geological activity in the recent past. Yet scientists didn't expect to see signs of such activity on a tiny world like Enceladus, which would fit comfortably within the borders of Arizona.

Cassini made two passes by Enceladus early this year. On February 16, the spacecraft came within 725 miles (1,167 km) of



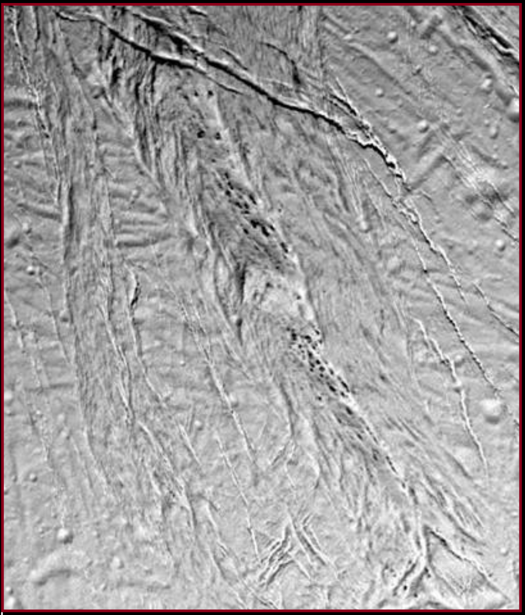
NASA/JPL/UNIVERSITY OF ARIZONA

A COLORFUL ENCELADUS indicates the water ice that makes up most of the surface comes in different particle sizes. The reddish regions in this visible and infrared mapping spectrometer image consist of larger grains and appear correlated with older, cratered areas. Blue showcases small grains and may be a sign of a more recent "snowfall."



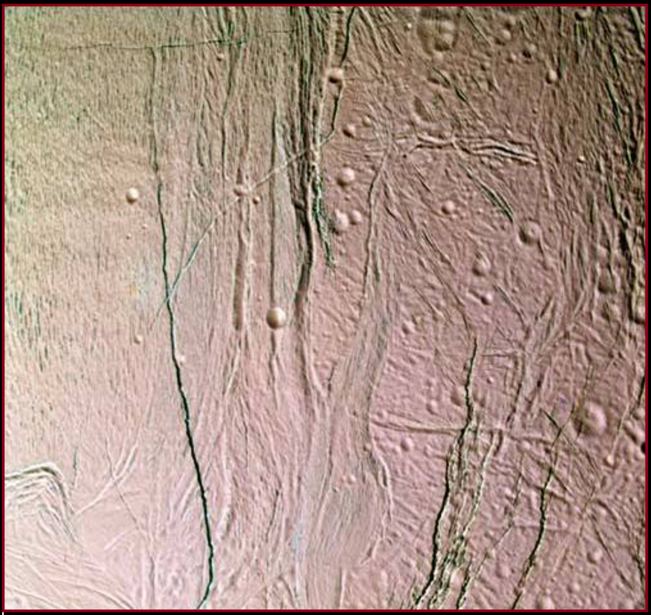
NASA/JPL/SSI

TECTONIC TROUGHS AND RIDGES border much older, cratered terrain in this false-color, global view of Enceladus. Sunlight illuminates the moon from the left, leaving the right edge in shadow.



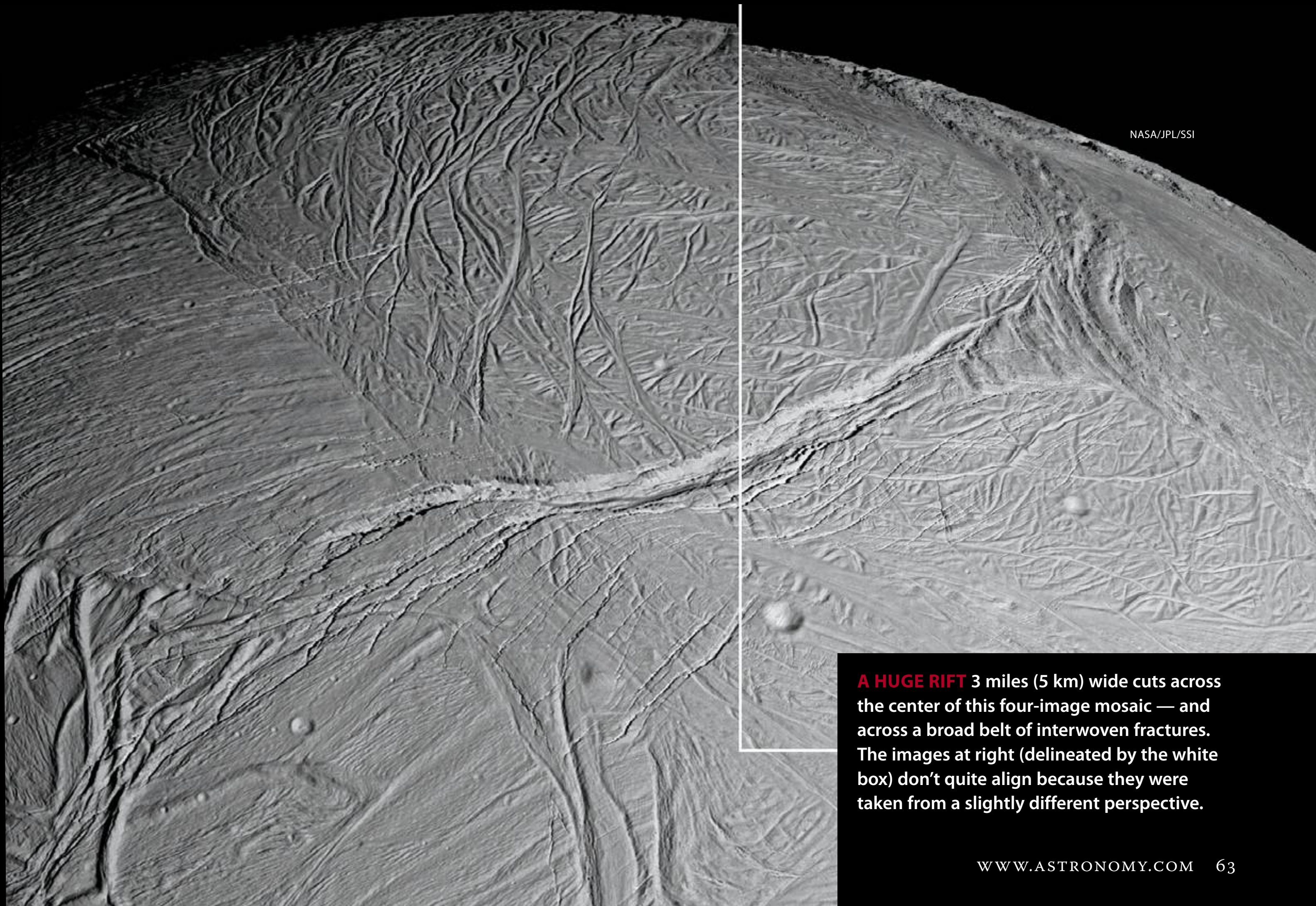
NASA/JPL/SSI

A SERIES OF MYSTERIOUS DARK SPOTS seems to form chains running parallel to fine fractures in this section of Enceladus. The spots are fairly small — even the largest are only about 2,500 feet (750 meters) across. Some scientists suggest the spots could be shadows cast by building-size outcrops, although no one knows for sure.



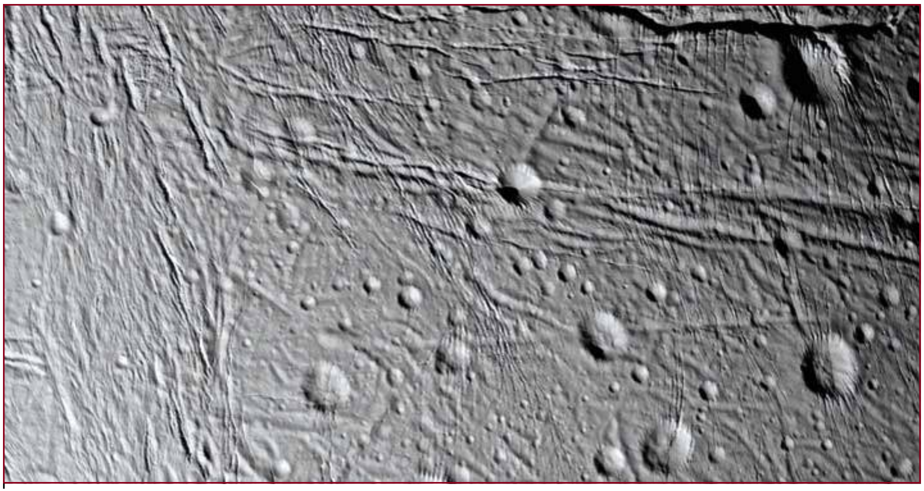
NASA/JPL/SSI

THE RIFTS AND GROOVED TERRAIN running down the center of this false-color image separate two distinct geological provinces. To the right lies older terrain peppered with craters as big as 6 miles (10 km) across and as small as Cassini's eye can see. To the left is a broad region of icy plains — cut by long, parallel grooves — that appears similar to parts of Jupiter's giant icy moon, Ganymede.



NASA/JPL/SSI

A HUGE RIFT 3 miles (5 km) wide cuts across the center of this four-image mosaic — and across a broad belt of interwoven fractures. The images at right (delineated by the white box) don't quite align because they were taken from a slightly different perspective.


NASA/JPL/SSI

FRACTURES SCORE much of Enceladus' surface. Here they cross all impact craters, meaning the fractures formed later in the moon's history. One fracture destroyed the northern wall of the 6-mile-wide (10-km) crater at top right. The east-west rifts measure a mile (1.5 km) wide, while the north-south fractures are as small as 330 feet (100 meters) across.

the moon's surface. One orbit of Saturn later, March 9, it skimmed by at an altitude of just 310 miles (500 km). In comparison, Voyager 2 passed 56,000 miles (90,000 km) away when it flew through the Saturn system in 1981. Thus, the Cassini encounters delivered images with up to 100 times better resolution.

An atmospheric moon

Cassini images didn't reveal gas molecules surrounding the moon, however. The atmosphere turned up in observations made by the spacecraft's magnetometer. Enceladus revolves around Saturn at a distance of 147,900 miles (238,000 km) — well inside the planet's enormous magnetic field. As the field sweeps past Enceladus, the moon slows and deflects charged particles trapped in the field. This diversion proved to be the smoking gun showing Enceladus possesses an atmosphere.

The magnetometer also detected magnetic field oscillations created by ionized molecules spiraling around the field lines. The frequency of these oscillations fingered the culprit: ionized water vapor.

Presumably, water vapor leaking from the surface gets ionized by the Sun's ultraviolet radiation, then Saturn's magnetic field whisks the molecules away. The extent to which Enceladus' atmosphere bent the magnetic field let scientists estimate the amount of water vapor being lost into space — some 5,000 tons per hour, enough to fill five Olympic-size swimming pools.

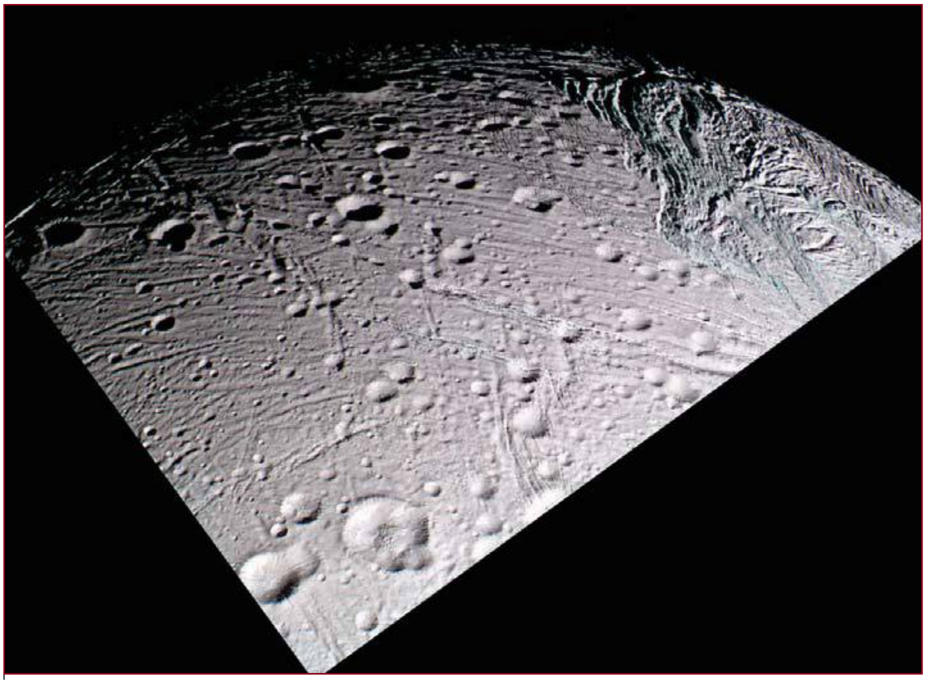
"It was a complete surprise to find these signals at Enceladus," says Michele Dougherty of Imperial College in London, principal investigator for the magnetometer experiment. Even though the Voyagers carried magnetometers, they didn't notice any magnetic field deflection from the moon. Perhaps those spacecrafts' greater distance placed the atmosphere beyond their detection capabilities, or maybe conditions at Enceladus have changed in the past 25 years.

Unlike its massive saturnian sister, Titan — 3,200 miles (5,150 km) in diameter and the only solar system moon with a thick atmosphere — Enceladus exerts too little gravitational pull to hold onto an atmosphere for long. That raises the intriguing possibility that ice volcanoes or geysers spew gases from the moon's interior. If such eruptions take place, Enceladus would join Jupiter's Io and Neptune's Triton as the only active moons known.

Enceladus' icy nature means any activity would more likely resemble the ice geysers seen on Triton than the molten-rock volcanism of Io. Such eruptions could explain the saturnian moon's brightness. As water blasts out, bigger droplets would freeze and fall back to the surface, coating it with a bright patina of fresh ice.

Saturn's E ring also suggests active venting on Enceladus. This tenuous ring — the outermost in Saturn's magnificent ring system — reaches peak density at Enceladus' distance from the planet. The icy particles that make up the E ring are tiny, about 1 micrometer across (the size of typical smoke particles). As with Enceladus' atmosphere, the E ring could not survive for more than a few thousand years without replenishment.

Tides seem the only plausible source for the heat needed to drive such geological


NASA/JPL/SSI

THE CRATERED TERRAIN in this false-color mosaic is older than much of Enceladus' surface. The large crater at bottom measures 12 miles (20 km) across and has a prominent dome in its center. Note this older terrain's softer appearance compared with the crisp topography in the network of ridges and troughs at upper right.

Richard Talcott *is a senior editor of* Astronomy.

activity. Saturn's immense gravity raises a tidal bulge in Enceladus, and the moon flexes because its orbit is not a perfect circle. An orbital resonance — Enceladus orbits Saturn twice in the time it takes the larger moon Dione to orbit once — keeps Enceladus in a slightly elliptical orbit, which continually flexes and heats its interior. (Coincidentally, Jupiter's moons Io and Europa also are locked in a 2:1 orbital resonance.)

An icy surface

The amount of tidal heating might not be enough to melt much of the interior, however. Ices make up the bulk of Enceladus. Yet pure water ice melts at a much higher temperature — and thus requires more internal heating — than ices containing a mix of ammonia or carbon dioxide.

Observations made with Cassini's Visual and Infrared Mapping Spectrometer show no trace of the expected ammonia or carbon dioxide at the surface. "The spectra look like laboratory-fabricated water ice, indicating the ice is quite pure," says Roger Clark of the U.S. Geological Survey in Denver.

The icy surface held other surprises for scientists. Cassini's camera added lots of detail to the picture painted by Voyager. It recorded impact craters, to be sure, but it also discovered large tracts of the smooth plains etched with a complex system of fractures and resurfaced terrain. In some cases, the fractures cross craters, implying they formed later.

Planetary scientists count craters to estimate the age of an object's surface. Because impacts continue to pelt the outer solar system (although at a much lower rate than early in the solar system's history), areas lacking impact scars must have been wiped clean. It's the same reason our cold, dead Moon has so many impact craters while tectonically active Earth has few.

Overall, Enceladus' topography varies by only a couple of thousand feet (about 1 km). That's a tiny amount for such a small, low-gravity object; another piece of evidence pointing to widespread interior melting and resurfacing.

"The icy surface of Enceladus appears to have similarities to both Europa and Ganymede — two prominent icy satellites of Jupiter," says Carolyn Porco of the Space Science Institute in Boulder, Colorado, and leader of Cassini's imaging team. "Both Europa and Ganymede are thought to have subsurface water layers, or 'oceans,' so the similarities with Enceladus are intriguing."

A long history of intense tectonic activity obviously shaped Enceladus. Older regions show more impact craters and have a soft, muted look. Scientists think these areas have been covered by a layer of icy particles likely erupted from the interior. Topographic features in younger terrain show crisper relief.

The young terrains' top layer appears uniform in color, which suggests material with a homogeneous composition and grain size covers them. But many fractures seem to penetrate down to material with a slightly different color. Planetary scientists suspect the walls of these fractures expose outcrops of solid ice, or ice with different grain sizes than the powdery material that blankets flat surfaces.

Older fractures don't show the same color as younger ones — what you'd expect if icy particles draped the older features. However, the color contrast could indicate a difference in composition between buried ice and surface ice, although no evidence for such a difference has surfaced yet.

One new mystery popped up in the Cassini images. Some areas show a series of small dark spots between 400 and 2,500 feet (125 and 750 meters) in diameter. In many places, the spots seem aligned in chains that run parallel to narrow fractures. The spots could reflect regions with a different composition, but so far no one has come up with a good explanation.

The two Enceladus flybys seem to raise as many questions as answers. Planetary scientists will spend months, if not years, analyzing all the observations, trying to put together a coherent picture of this tortured world. Cassini will provide further help when it passes close to Enceladus again in July 2005 and March 2008. Perhaps by then, researchers will have better models to test against Cassini's reality.

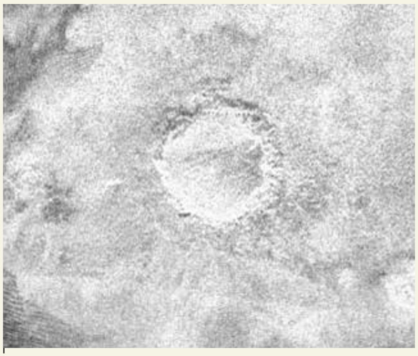
/// PUNCHING HOLES IN TITAN

In addition to the two recent encounters with Enceladus, Cassini continues to make close passes by Saturn's largest moon, Titan. The enigmatic, haze-shrouded world gives up more secrets with each flyby, although not in the rush that accompanied the landing of the European Huygens probe January 14 (see "Titan touchdown," April 2005). To build as complete a picture as possible, planetary scientists plan more than 40 flybys during Cassini's 4-year mission orbiting Saturn.

One of the most-anticipated findings came during a February 15 flyby. Cassini's radar discovered two large impact craters, one approximately 37 miles (60 km) in diameter, the other 273 miles (440 km) wide. Wayward comets and asteroids should pound Titan just as they have Saturn's other moons, but until the radar detection, Cassini scientists had turned up only tantalizing clues.

"The appearance of the small crater and the extremely bright, hence rough, blanket of material surrounding it indicates an origin by impact," says Jonathan Lunine, a Cassini interdisciplinary scientist from the University of Arizona. Scientists estimate it formed when an object 3 to 6 miles (5 to 10 km) in diameter smashed into the moon's surface. The crater has no central peak, leading scientists to think erosion or some other process has modified its appearance. Perhaps rainfall — in Titan's case, that would mean liquid methane — winds, or a softening of the icy surface material did the trick.

Radar images of the larger crater, dubbed "Circus Maximus" by scientists, show sinuous channels that appear to flow down the crater's eastern ramparts. Scientists suspect liquid methane carved these features. This area appears somewhat similar to the rubble-strewn plains where Huygens landed. — *R. T.*



NASA/JPL

A BLAST IN THE PAST created this crater on Titan, seen here in a radar image. The crater measures 37 miles (60 km) across and was created when a miles-wide projectile crashed into the moon. The crater's bright surroundings represent debris excavated by the crater's formation.

Ask Astro

Moonbows and supernova menagerie

MOONBOWS

I saw a rainbow caused by moonlight.

How often does this occur? — **ED STERBENC,** PALO ALTO, CALIFORNIA

Lunar rainbows — moonbows — occur less than 10 percent as often as normal rainbows. Moonbows need a few additional conditions to form, which is why they're so rare.

Although well known, rainbows themselves are not common — most places see fewer than six in a year. Locations with frequent, brief showers mixed with clear skies and bright sunshine see many more. The Isle of Skye on Scotland's west coast and Hawaii are both places with frequent rainbows.

To make a rainbow, we need bright sunshine and a screen of rain opposite the Sun, but even that's not enough. Both rainbows and moonbows need almost perfectly spherical raindrops — distortions of only 1 percent are sufficient to prevent a bow's appearance.

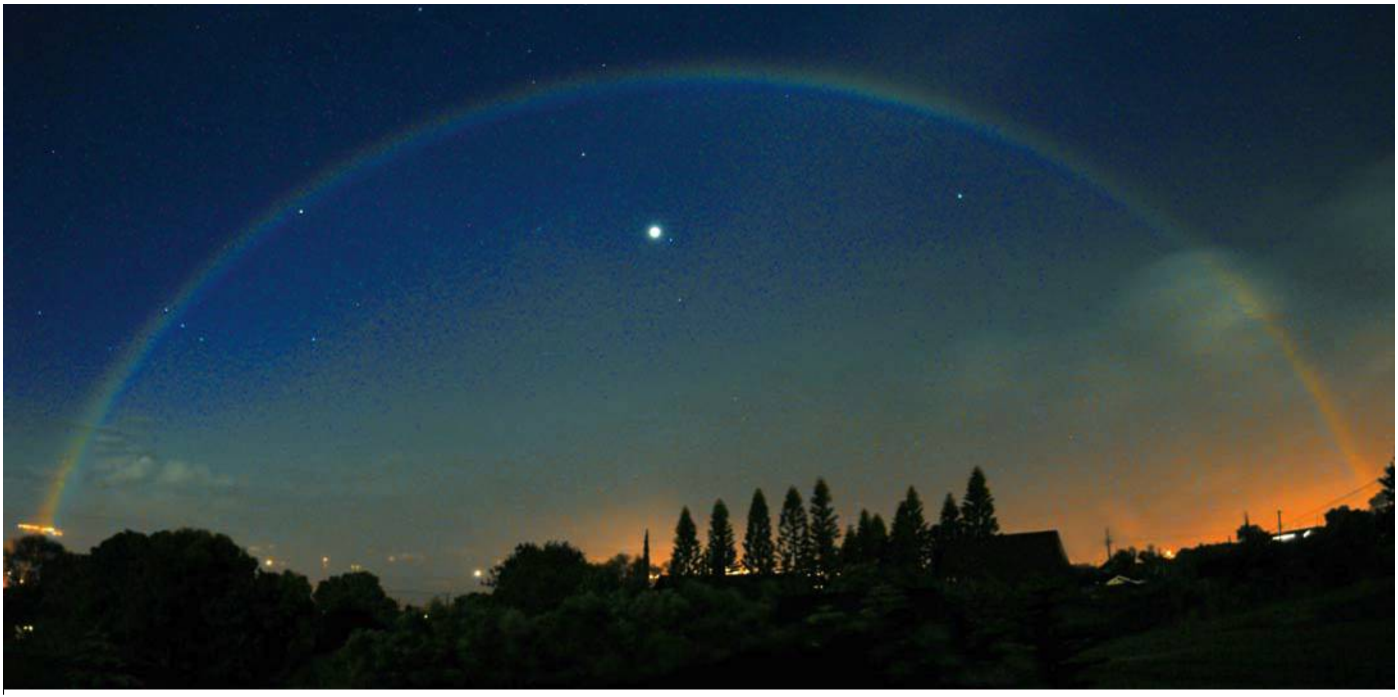
Also, the light source must be at the right altitude. Rainbows and moonbows are centered directly opposite the Sun or Moon. The higher the light source's altitude, the lower the bow's arc. So, the Sun or Moon must be low enough that their bows form above the horizon.

However, moonbows need something more. While lunar rainbows form in exactly the same way as with the Sun, the Moon is bright enough to make visible moonbows only for about 3 days around Full Moon.

Moonbows are faint and must be viewed against a dark sky near the end of evening twilight. If you wait too long, the Moon will rise so high that any moonbow it creates lies below the horizon.

In middle latitudes, the Full Moon is best placed for moonbows in summer, when it spends more time low in the sky. In other seasons, the window of opportunity for catching a moonbow may last only an hour.

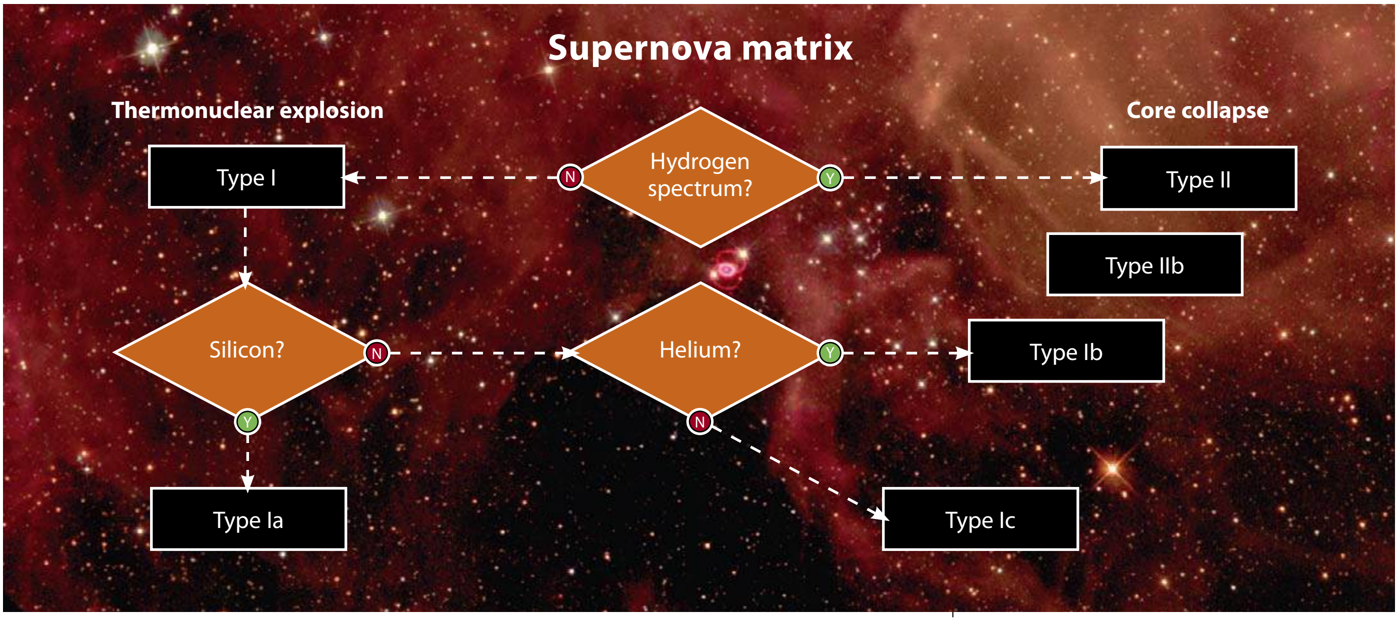
In showery weather, always look for a pale moonbow when the Moon is low and bright. A moonbow actually is colored like its daytime counterpart, but its light is mostly too dim to activate the color sensors in our eyes. A camera mounted on a tripod will capture the colors easily, but our eyes



ROB RATKOWSKI/MAUI

A MOONBOW ARCS over the Hawaiian island of Maui in May 2004, nearly centered on bright Venus. Moonbows usually look pale to our eyes because there isn't enough light to excite color receptors. However, the camera recorded subtle color bands.

Send your questions via e-mail to: askastro@astronomy.com; or write to: Ask Astro, P. O. Box 1612, Waukesha, WI 53187. Be sure to tell us your full name and where you live. Unfortunately, we cannot answer all questions submitted.



BACKGROUND: NASA/STSCI/ESO

ASTRONOMERS DISTINGUISH supernovae primarily based on the chemical signatures in their light. Type Ia supernovae arise from thermonuclear explosions in white dwarfs. Type Ib, Ic, and type II events occur when the cores of massive stars run out of fuel and collapse.

and brain alone are all that are needed to experience the wonder of the Moon's own rainbow. — **LES COWLEY,** NORFOLK, ENGLAND

SUPERNOVA MENAGERIE

I've heard of type Ia supernovae. What are the other type I varieties? — **TIM HUPP,** ELKTON, VIRGINIA

Astronomers recognize three flavors of type I supernovae: type Ia, Ib, and Ic. Type Ia supernovae occur in binary systems, where matter from a normal companion star flows onto a white dwarf. The white dwarf gradually gains mass until it becomes unstable and explodes. Another possible source for this supernova type is the merger of two white dwarfs.

The maximum brightnesses of type Ia supernovae vary little, a feature that makes them important "standard candles" that help astronomers determine distances to other galaxies. Spectra show these exploding stars contain no hydrogen; but at peak brightness calcium, oxygen, and silicon lines appear. Type Ia supernovae are found in all types of galaxies. A recent example is SN 2005as in NGC 3450.

Supernovae of type Ib and Ic display apparent energies 10 or more times greater than other supernovae. Found only in spiral galaxies, Type Ib and Ic supernovae are thought to be associated with massive stars that have lost their hydrogen envelopes either by strong stellar winds (as in Wolf-Rayet stars) or through mass loss to a binary companion. Neither class shows spectral hydrogen or silicon lines. The presence of helium lines distinguishes type Ib.

Light from type Ib and Ic supernovae is highly polarized, implying these stars explode in some preferred direction. The remnants of some supernovae, such as Cassiopeia A and SN 1987A, hint that the explosion process can involve twin jets of material shot out along the star's spin axis.

This "beaming" explains why these supernova classes appear much more energetic than all other types — so much so that some astronomers dubbed them "hypernovae." If the star's axis tips toward Earth, astronomers record rapid expansion speeds from the small amount of matter ejected in the jets. When astronomers account for the jets' beaming effect, the apparent extraordinary energy of these supernovae disappears.

Type Ib/c events are linked with gamma-ray bursts (GRBs) longer than 2 seconds, although it remains unclear whether other supernova types are also capable of producing a GRB. Famous examples include SN 1998bw (associated with GRB 980425) and SN 2003dh (linked with GRB 030329).

It was 1941 when astronomers first recognized not all supernovae are alike. German astrophysicist Rudolph Minkowski proposed a simple two-level scheme based on the absence (type I) or presence (type II) of strong hydrogen spectral lines when a supernova reaches peak brightness.

Type II events occur in massive stars that are surrounded by thick, massive hydrogen atmospheres.

One variant, type IIb, shows prominent hydrogen lines right after the explosion, but the spectrum later morphs into something that looks more like it came from a type Ib or Ic supernova. Astronomers think these events bridge the gap between supernovae from stars that have kept massive hydrogen atmospheres and type Ib/c events, which come from stars that have lost these envelopes completely. — **FRANCIS REDDY,** ASSOCIATE EDITOR

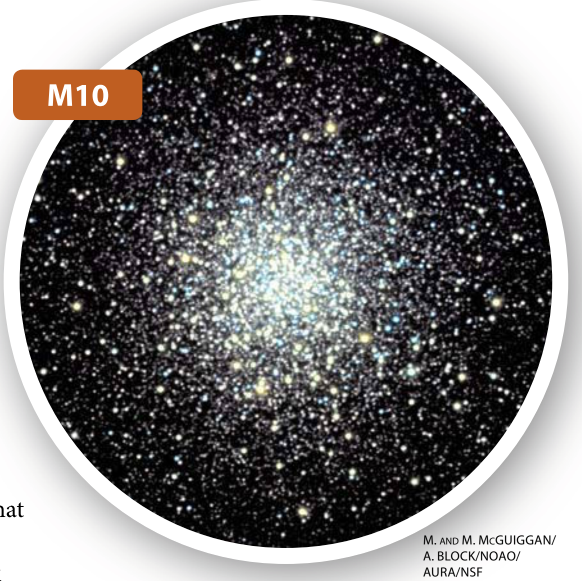
A DEEP-SKY YEAR

Set up your scope, pour a cool drink, and follow this step-by-step guide to explore the season's best sights. /// BY IAN RIDPATH

Summer splendors

Summer is a great time to start observing. The temperatures treat you and your equipment kindly. Overhead, a dragon wraps around the North Pole. Mythmakers of old knew it as Ladon, the dragon slain by Hercules. To us, it's the constellation Draco. Most distinctive is its head, a distorted diamond of four stars.

M10



M. and M. McGUIGGAN/ A. BLOCK/NOAO/ AURA/NSF

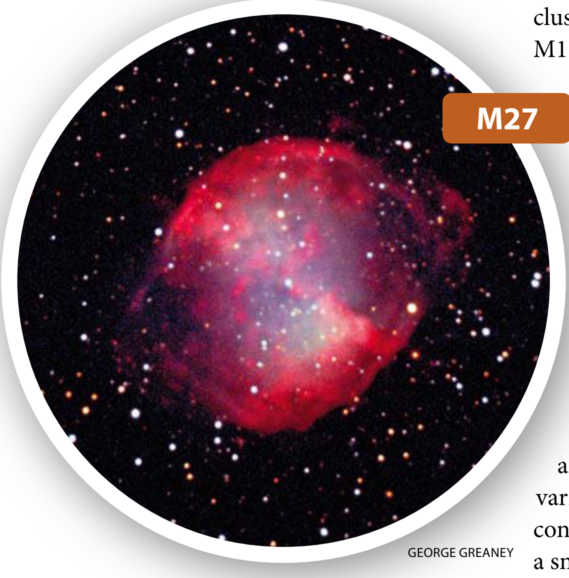
OPHIUCHUS HOLDS several globular clusters. Although M10 is not the richest, you can resolve stars close to its core.

The faintest of these, **Nu (ν) Draconis** [tour stop 1], is an outstanding set of white 5th-magnitude stars that looks like a pair of cat's eyes — an excellent target for binoculars.

A wider 5th-magnitude pair is **16** and **17 Draconis** [2], the brighter of which deserves a closer look with a small telescope. High magnification divides it into two, making this a triple star system.

South of the dragon lies its conqueror, Hercules, a constellation well-stocked with notable double stars. Among the best of them for small apertures are **Kappa (κ) Herculis** [3] (whose stars glow at magnitudes 5 and 6) and **Rho (ρ) Herculis** [4] (both 5th magnitude).

M27



GEORGE GREANEY

THE DUMBBELL NEBULA in Vulpecula is a Sun-like star's death shroud. You can observe it easily with a small scope.

Hercules' main tourist sight, though, is the great globular cluster **M13** [5], the finest object of its type north of the celestial equator. M13 lies along one side of the Keystone, a quadrilateral of 3rd- and 4th-magnitude stars that marks the hero's body. You can glimpse M13 with your unaided eye under a dark sky, and it's found easily with binoculars, appearing half the width of the Full Moon. Small telescopes reveal the brightest supergiants among its 300,000 or so stars.

Hercules contains a second globular cluster, **M92** [6], fainter and smaller than M13 but still well worth seeking out. Through binoculars it appears starlike and might be overlooked, but a small telescope reveals its true nature. With an estimated age approaching 13 billion years, M92 is the oldest known globular.

Alpha (α) Herculis [7] is an immense red giant 400 times the diameter of the Sun. Like other bloated stars, it is unstable, fluctuating erratically in size and brightness. It can appear anywhere between 3rd and 4th magnitude. As well as being variable, Alpha Herculis is a double of contrasting colors. High magnification on a small telescope shows a magnitude 5 blue-green companion.

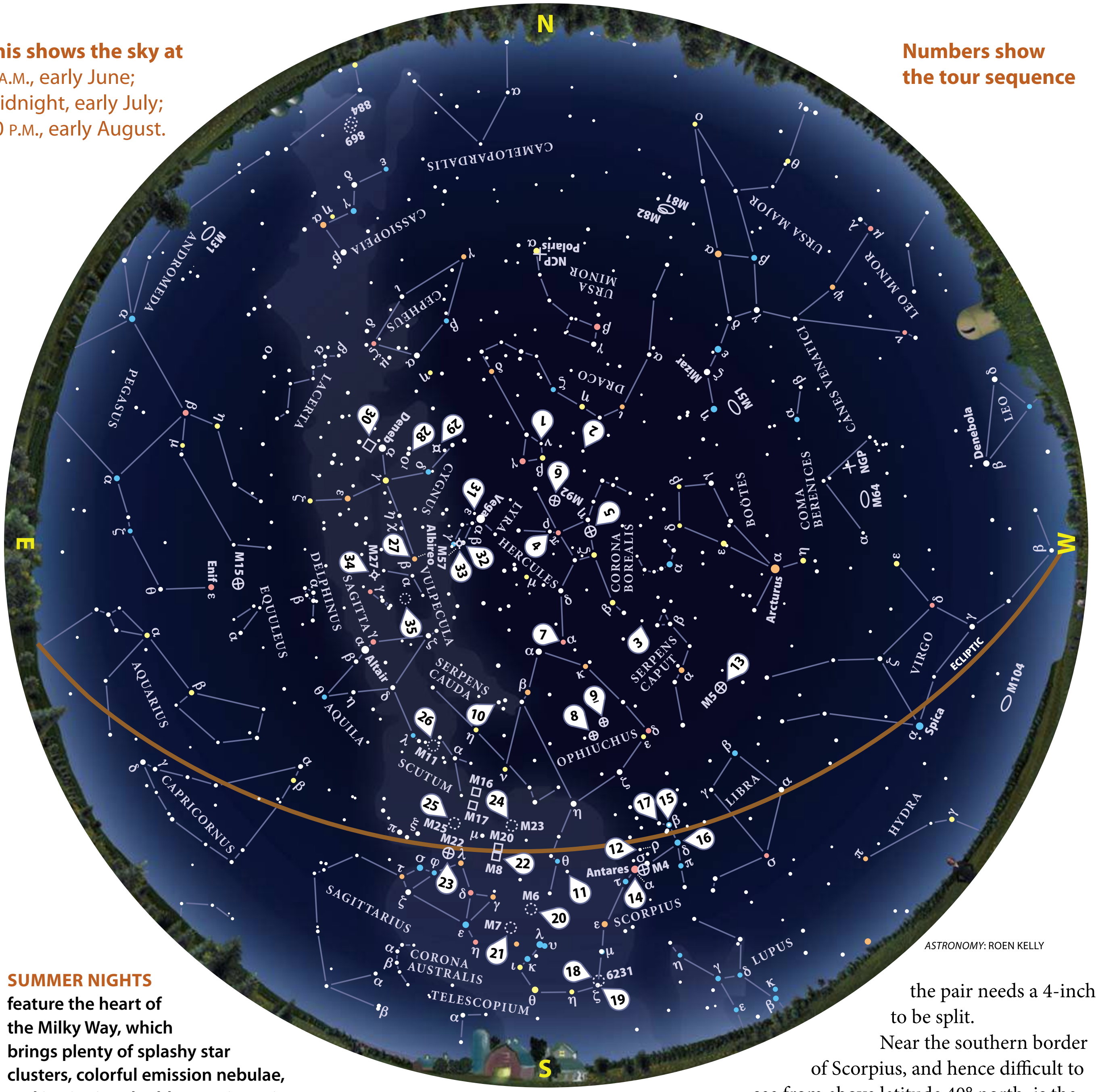
Hercules stands head to head with another giant in the sky, Ophiuchus, a constellation studded with seven globular clusters in the Messier catalog. The brightest are **M10** [8] and **M12** [9], but neither rivals M13 in Hercules.

Bereft of bright stars and with a tongue-tying name, Ophiuchus may seem unfashionable, but don't use that as an excuse for failing to seek two excellent doubles and a remarkable multiple star there. Start with **70 Ophiuchi** [10], a colorful yellow and orange pair of magnitudes 4 and 6. Now, look in the constellation's southernmost reaches to find **36 Ophiuchi** [11], a warm-colored binary of 5th-magnitude orange stars divisible with small apertures.

To the north of Antares, which lies in neighboring Scorpius, you'll find the fascinating multiple star, **Rho Ophiuchi** [12]. Two magnitude 7 companions flank the magnitude 5 primary star. High power reveals the primary has a much closer magnitude 6 companion.

This shows the sky at
2 A.M., early June;
midnight, early July;
10 P.M., early August.

Numbers show the tour sequence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BOÖTES
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DELPHINUS
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SAGITTA
Altair
AQUILA
AQUARIUS
SERPENS CAUDA
SERPENS CAPUT
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ASTRONOMY: ROEN KELLY

SUMMER NIGHTS feature the heart of the Milky Way, which brings plenty of splashy star clusters, colorful emission nebulae, and intriguing double stars into view.

Ophiuchus is depicted as a man coiled by a large snake — Serpens — the only constellation divided in two. In his left hand, Ophiuchus holds the snake's head, Serpens Caput, wherein lies **M5** [13], the second-best globular in the northern sky.

Ophiuchus stands on the body of Scorpius the Scorpion. Because both Scorpius and its neighbor Sagittarius lie south of the celestial equator, atmospheric extinction dims their glory from northern latitudes. However, everyone should be able to find **Antares** (Alpha Scorpii) [14], the bright star marking the heart of the scorpion. Antares is a red supergiant 400 times larger than the Sun.

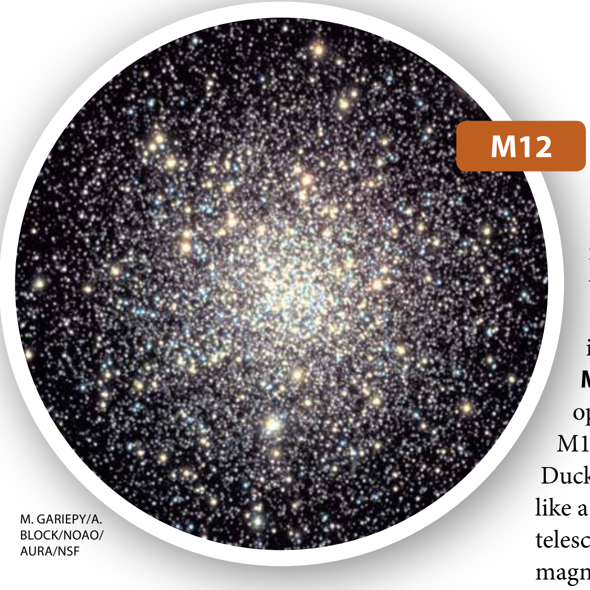
In the head of the scorpion lies **Beta (β) Scorpii** [15], a double of 3rd- and 5th-magnitude stars. Beta Scorpii splits easily with small telescopes and is just within range of steadily held 10x50 binoculars. The star in the middle of Scorpius' head, **Delta (δ) Scorpii** [16], is a recently discovered variable star. Prior to 2000, it shone steadily at magnitude 2.3, but then it began to brighten, reaching magnitude 1.6.

Just east of Beta Scorpii lies **Nu Scorpii** [17]. Small telescopes or 10x50 binoculars show it as a wide double of 4th and 6th magnitudes. Each of these stars is itself a close pair — the fainter star can be divided with a 3-inch scope, while the brighter of the pair needs a 4-inch to be split.

Near the southern border of Scorpius, and hence difficult to see from above latitude 40° north, is the large open cluster **NGC 6231** [18]. It's visible through binoculars like a mini-Pleiades in a rich area of the Milky Way. Nearby is the wide double **Zeta (ζ) Scorpii** [19].

Next to the scorpion's stinger lie the glorious open clusters **M6** [20] and **M7** [21]. M6, popularly known as the Butterfly Cluster because of its shape, is elliptical, and its brightest star, BM Scorpii, is an orange giant that varies between magnitudes 5 and 7.

M7, the most southerly Messier object, can be seen with the naked eye as a bright knot in the Milky Way. Its apparent diameter is more than twice that of the Full Moon. M7's central stars are arranged in an X, while the outliers form a triangle.



M. GARIEPY/A. BLOCK/NOAO/AURA/NSF

SEVEN MESSIER GLOBULARS call Ophiuchus home; M12 stands among the finest.

Next we come to Sagittarius, in the direction of the center of our galaxy. Sagittarius is decorated with 15 Messier objects — more than any other constellation. Start with the **Lagoon Nebula** (M8) [22], a milky glow 3 Moon diameters long with a dark rift down its center.

Near M8 is **M22** [23], another fine globular cluster. Binoculars show it as a 5th-magnitude wooly ball about two-thirds the diameter of the Moon. A 3-inch telescope will resolve its brightest stars. Two notable open clusters in Sagittarius for binoculars and small telescopes are **M23** [24], an elongated field of faint stars, and **M25** [25], which is large and scattered.

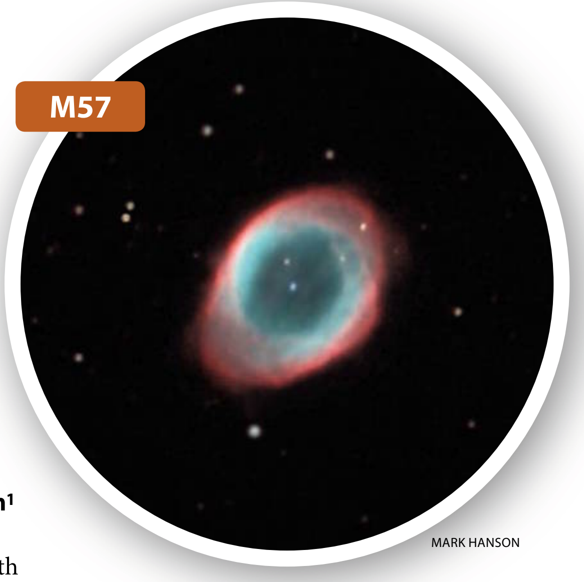
Move north along the Milky Way into Scutum the Shield to encounter **M11** [26], one of the most charming open star clusters of the summer sky. M11 is popularly known as the Wild Duck Cluster because it's V-shaped, like a flock of wildfowl in flight. Small telescopes show the V with an 8th-magnitude star at the apex.

Move north again to reach Cygnus the Swan. Cygnus also is known as the Northern Cross, a bigger version of its tiny southern counterpart. Marking the swan's beak is **Albireo** (Beta Cygni) [27], one of the top 10 showpieces for small scopes. Albireo is a colorful pair of 3rd- and 5th-magnitude stars, wide enough to be separated even in 10x50 binoculars. Most observers see the stars as golden and sapphire-blue.

A wider version of Albireo is **Omicron^1 (ο^1) Cygni** [28] — my favorite binocular double — a magnitude 4 orange giant with a 5th-magnitude turquoise companion. Completing the picture is a magnitude 7 blue companion visible in small telescopes.

A showpiece in this area is the **Blinking Planetary** (NGC 6826) [29], which, with sufficient magnification, shows a disk larger than Saturn's. NGC 6826 is known as the Blinking Planetary because it appears to wink on and off as you look alternately toward it and away again. This is due to the workings of averted vision, which brings the magnitude 10 central star into view when you look to one side of the star. At the edge of the same field of view, note the magnitude 6 pair that comprises 16 Cygni.

Ian Ridpath *is author of* The Monthly Sky Guide *(Cambridge University Press) and* The Princeton Field Guide to Stars and Planets *(Princeton University Press).*

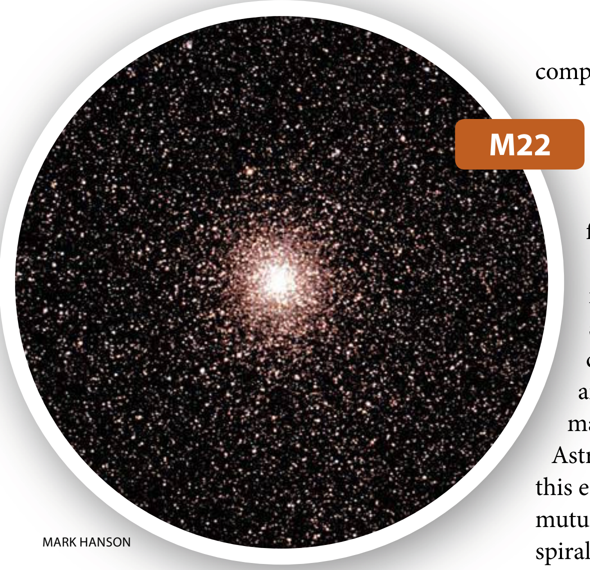


MARK HANSON

THE RING NEBULA is one of the most famous planetary nebulae. It can be found between two of Lyra's bright stars.

JACK HARVEY AND TOM DAUGHTERY/ADAM BLOCK/NOAO/AURA/NSF

THE LAGOON NEBULA in Sagittarius is a stunning emission nebula with a dark lane of dust and cold gas dividing it in two.



MARK HANSON

ONE OF THE BRIGHTEST globular clusters, M22 in Sagittarius can be glimpsed with the naked eye from a dark site.

Another famous object in Cygnus, although much less impressive visually than on photographs, is the **North America Nebula** (NGC 7000) [30]. NGC 7000 is more than 3 Moon diameters across, but you'll need dark skies to pick it out from the Milky Way background.

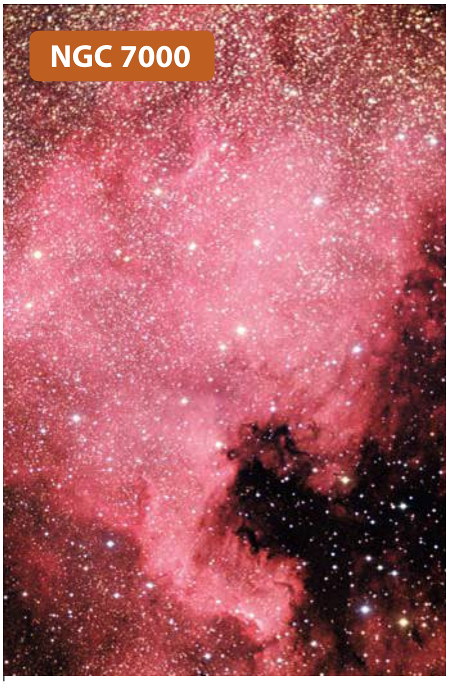
Across the Milky Way is Lyra the Harp. In the same binocular field as its brightest star, Vega (Alpha Lyrae), is **Epsilon (ε) Lyrae** [31], a wide double star with two equally matched magnitude 5 components. Epsilon Lyrae is popularly known as the Double Double because each of the components is itself a binary, just divisible with high magnification in a 2.4-inch scope. Every observer should attempt to resolve all four components of the Double Double, the finest quadruple star in the sky.

Another fascinating multiple star is **Beta Lyrae** [32]. Small telescopes show it as an attractive double of cream and blue. The brighter star is an eclipsing binary, ranging from magnitude 3.3 to 4.4 every 12.9 days. Astronomers deduced the two stars in this eclipsing binary are elongated by their mutual gravity and are shedding gas, which spirals into space.

It's probably a safe bet that Lyra's most-imaged object is the **Ring Nebula** (M57) [33], a famous planetary nebula. It lies nearly halfway from Beta to Gamma (γ) Lyrae and can be picked up in small telescopes as an oval patch larger than the apparent disk of Jupiter.

The easiest of all planetary nebulae to see lies in adjacent Vulpecula the Fox — the **Dumbbell Nebula** (M27) [34]. Small telescopes show the double-lobed shape that gives the object its popular name. Unlike most planetary nebulae, which are small, the Dumbbell is unexpectedly large, about 10 times Jupiter's apparent diameter.

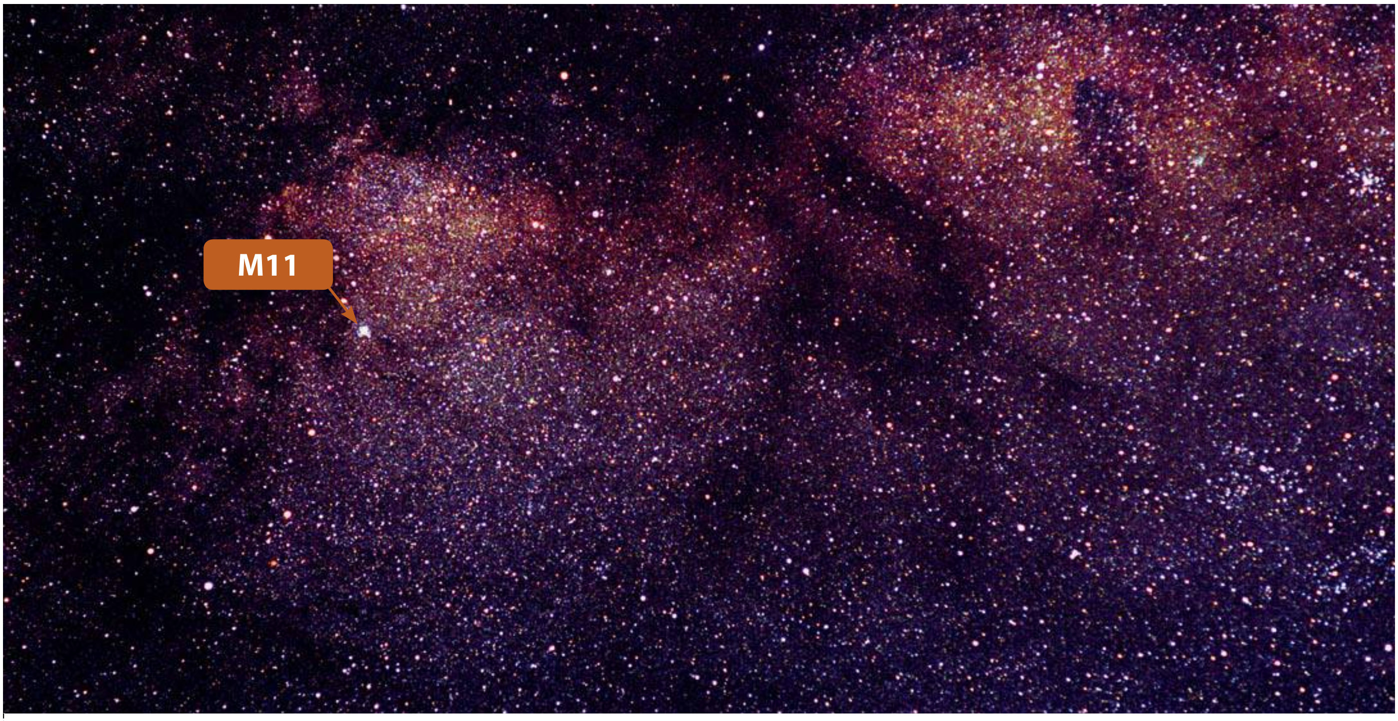
One of my favorite objects is the **Coathanger** [35], also known as Brocchi's Cluster and Collinder 399. About halfway between Albireo and Altair, the Coathanger consists of a line of six stars with a curve of four stars that protrudes from its center and forms the hook. This asterism is easy to find in binoculars, and its amusing shape is sure to send you to bed with a smile.



MARTIN AND GERDA VAN DER VOORT/ADAM BLOCK/NOAO/AURA/NSF

THE NORTH AMERICA NEBULA in Cygnus lies just 3° east of the constellation's brightest star, 1st-magnitude Deneb.

ONLINE EXTRA For summer "challenge" objects, see www.astronomy.com/toc



JOHN CHUMACK

THIS WIDE-FIELD VIEW of the constellation Scutum the Shield reveals the rich Wild Duck Cluster (M11) to the left of center.

ECLIPSE CHASING

On March 29, 2006, observers across eastern South America, northern Africa, and western Asia will be treated to a total solar eclipse. /// BY FRED ESPENAK AND PATRICIA TOTTEN

Corona light

Following the mysterious fading of sunlight, when everything turns black in the middle of a sunny day, it's enough to make people panic. But not those who know it's an eclipse of the Sun. The next opportunity for people to marvel at the rare beauty of the eclipsed Sun's corona and other glowing effects is March 29, 2006.

The Moon's umbral shadow will first touch down in Brazil and then sweep northeast across the Atlantic. It will pass through northern Africa and parts of eastern Turkey. After crossing the Black Sea and entering central Asia, the shadow will rush off the planet's edge at sunset in western Mongolia.

People often wonder, what is so addictive about a total solar eclipse? It certainly is difficult to explain totality's allure to those who have never observed it. Beautiful, awe-inspiring, and rare — all three qualities make it addictive.

Fred Espenak *has experienced 18 total eclipses while* **Patricia Totten** *has seen eight. Since they now chase these events together, Totten despairs of ever catching up to "Mr. Eclipse."*

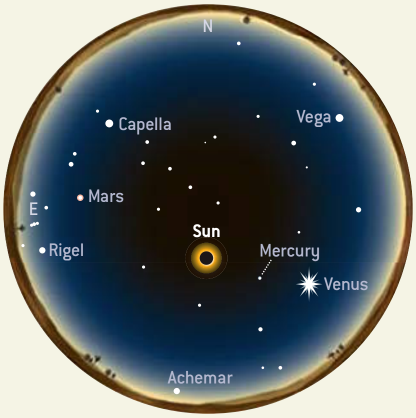
Think of physical wonders on Earth — Victoria Falls, the Egyptian pyramids, the Grand Canyon. Now imagine these amazing sights can be seen only for a few minutes every 2 years or so, and they're in a different place each time. Given these limitations, the experience of viewing such a wonder would be even more treasured. Also, because fewer people would have witnessed them, the crowds would be enormous to see them.

/// THE HEAVENS DURING TOTALITY

During the 2006 total eclipse, the Sun is in southern Pisces. Three naked-eye-viewing planets and a few bright stars will be above the horizon within the total eclipse's path, which makes for a nice effect.

The most visible planet during totality will be Venus, located 47° west of the Sun. Mercury lies halfway between the Sun and Venus. However, it will prove more challenging to detect because it will be more than 5 magnitudes fainter than Venus. Mars lies 73° east of the Sun and will be slightly fainter than Mercury.

A finder chart will be an important tool to identify daytime constellations. Especially noticeable will be the summer triangle, with Vega at its vertex. — *F. E.*



FRED ESPENAK/ASTRONOMY: ROEN KELLY

TOTALITY PLUNGES OBSERVERS into darkness, allowing them to view daytime constellations, Venus, Mercury, and Mars.

PATRICIA TOTTEN

A TOTAL SOLAR ECLIPSE allows observers the rare view of the Sun's corona. This composite image from the August 11, 1999 eclipse shows solar prominences, the corona, and the "diamond-ring" effect.

A total eclipse's rarity pulls us around the world year after year. One observation isn't enough. Sometimes we travel, literally, to the ends of Earth — Iceland in May 2003 and Antarctica the following November — to be caressed by the Moon's fleeting shadow. During totality we are able to see our star in all its glory.

Please remember: Never look at the Sun's disk directly. It can cause severe eye damage, even blindness. See "Glenn Chaple's observing basics" on page 20 for more tips on solar observing.

If travel isn't in your plans, a partial eclipse can be seen from easternmost Brazil, the northern two-thirds of Africa, all of Europe, and central Asia. If you are able to travel, Libya, Egypt, and southern Turkey offer the best weather prospects and the easiest travel arrangements.

Brazil

The eclipse's 8,700-mile (14,000-kilometer) track begins in eastern Brazil, where the Moon's umbral shadow first makes contact with Earth at 8h36m UT. Here, totality lasts about 2 minutes. Natal, on the coast, is the only sizeable city in the Moon's path, but it's well off the center line. A coastal road allows observers to chase clear spots through the clouds.

The eclipse begins in the tropical climate of northeastern Brazil, where fog is common during the morning hours. Winds tend to be easterly, so any growing threat to visibility should come from the direction of sunrise. With the Sun low on the horizon, inland locations don't appear to offer any advantage, and low-lying areas also will be susceptible to morning fog.

After its brief kiss of Brazil, the umbra abandons land and races across the Atlantic Ocean during the next half hour.

North Africa

The Moon's shadow encounters Ghana's coast at 9h08m UT with the Sun 44° above the eastern horizon. Totality is predicted to last 3 minutes and 24 seconds. In Ghana's capital, Accra, residents can expect a total eclipse of just under 3 minutes.

Cloudy conditions will be prevalent over Ghana's coast, but fully overcast skies are rare. Fortunately by eclipse time, any morning fog should have burned off. During this time of year there are showers and thunderstorms, but a sunny spot usually can be found. Mobility will be an asset on eclipse day.

After leaving Ghana and the coast, the umbra will cross Togo, Benin, and Nigeria. Fog can be a problem this far inland, as the dry desert winds will not dominate until the path crosses into Niger.

The sudden darkness of the eclipse will only deepen the loneliness of this isolated area. Even though the duration of totality increases to 3 minutes 40 seconds, there will be few eyes to see it, as there are no large cities in the Moon's Niger path.

The shadow continues through northern Niger and northwestern Chad before entering Libya. In much of this area, the winds originate over the Sahara Desert and have little moisture. Sky conditions typically are sunny, but winds can fill the air with desert dust and sand, resulting in a reddish haze. Luckily, the probable impact of any dust on the eclipse would be to obscure visibility rather than to hide totality from view.

Libya

A new travel destination recently has opened up for United States citizens as a

TURKEY WITNESSES its second total solar eclipse in just 7 years. This image, from the August 11, 1999 eclipse, was taken as totality was over the city of Elazig.

FRED ESPENAK

FRED ESPENAK

MR. ECLIPSE combined 15 images of the June 21, 2001 total solar eclipse to create this stage-by-stage composite.

consequence of the improving relations with Libya. This country offers the best weather prospects for viewing the eclipse. However the paperwork required to travel there may be burdensome.

The eclipse maximum occurs over the Sahara Desert, just inside the Libyan border, where the frequency of sunny skies is the highest in the world. Greatest eclipse occurs at 10h11m18s UT with totality lasting slightly more than 4 minutes.

The shadow then proceeds toward the Mediterranean coast, where winds tend to be strong. Occasional dust storms can pop up, but serious ones are rare. Observers should be prepared to protect equipment from sand. Packing cameras and lenses in zip-lock bags may make all the difference in how the equipment functions.

The weather along the coast is more variable than in other parts of the African path. Cold fronts can produce thunderstorms, therefore coastal areas offer a diminished chance of clear skies.

As the shadow leaves Libya, it barely nicks Egypt's northwestern coast before beginning a 15-minute trip across the Mediterranean Sea.

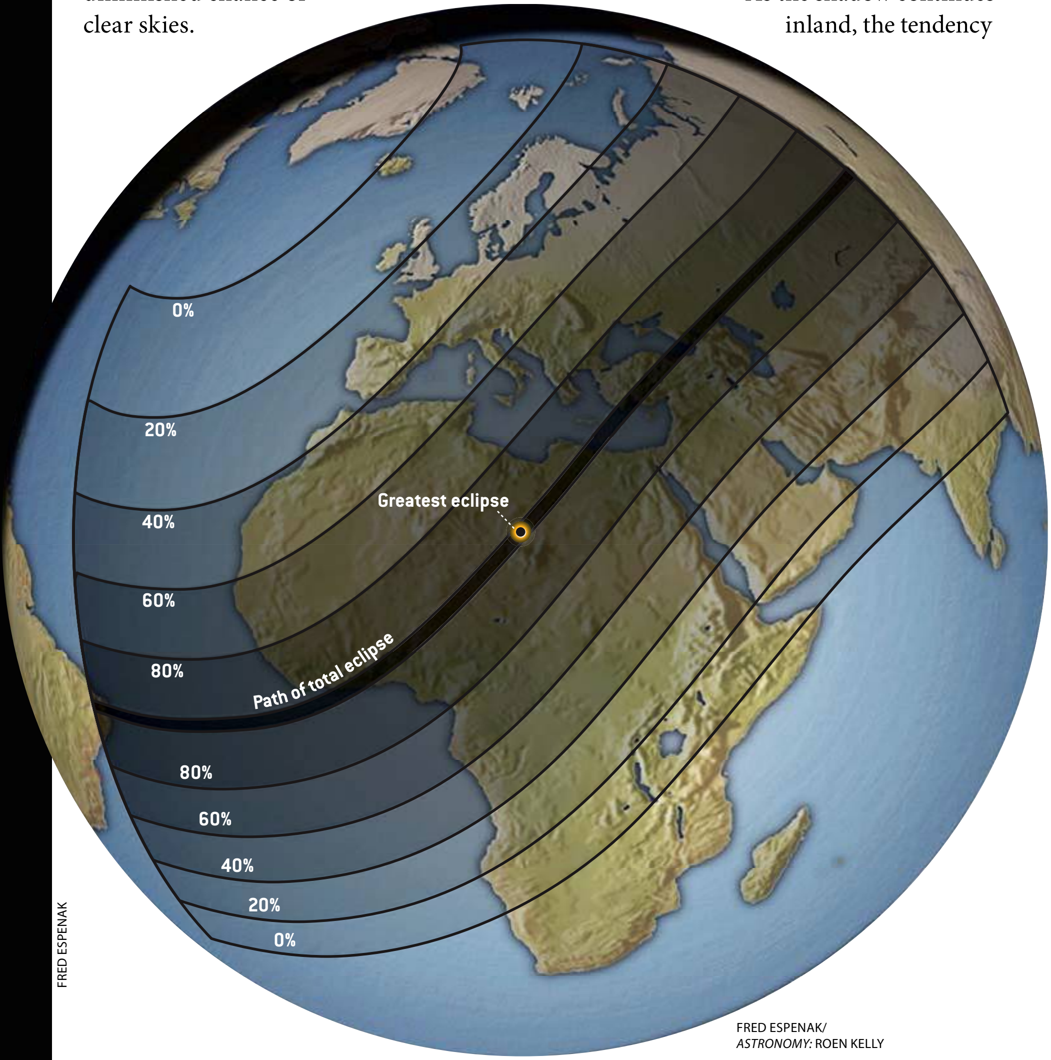
Mediterranean

Passing between Crete and Cyprus the shadow makes landfall on a tiny area of Greece, just 1.2 miles (2 kilometers) off the Turkish coast. The island of Kastelorizo, with a population of about 200, will experience 3 minutes of totality. In this quiet fishing community, the experience undoubtedly will spawn a tale passed on to future generations.

Turkey

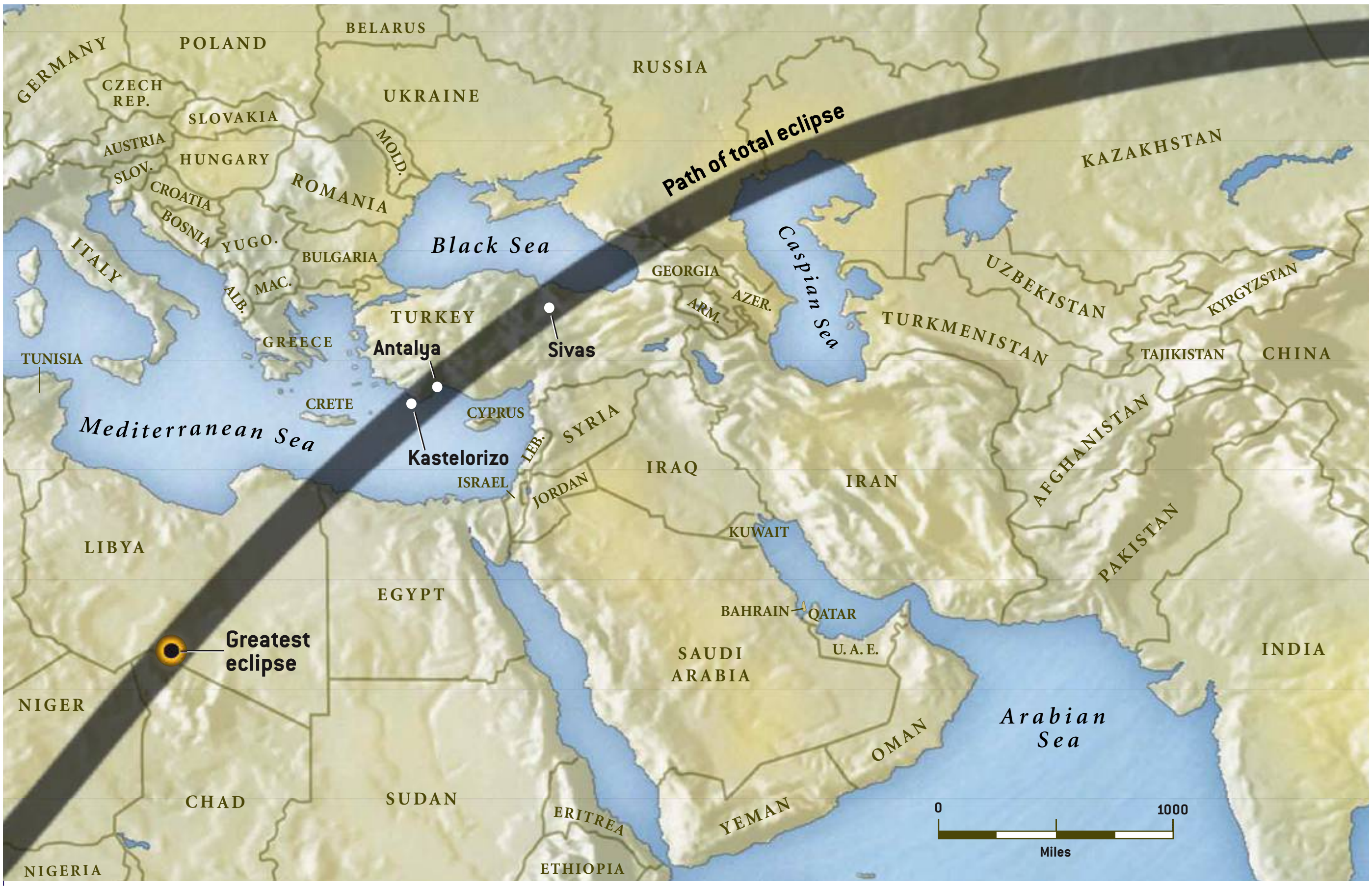
After sweeping across Kastelorizo, the shadow enters Turkey and quickly engulfs Antalya. This city of nearly 750,000 will be brushed by a total eclipse lasting 3 minutes and 11 seconds. Observers on the center line will receive an additional 35 seconds.

As the shadow continues inland, the tendency



FRED ESPENAK/
ASTRONOMY: ROEN KELLY

AFRICA AND ASIA likely will host more solar-eclipse chasers because of accessibility.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Path of total eclipse
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Caspian Sea
GEORGIA
ARM.
AZER.
UZBEKISTAN
KYRGYZSTAN
TURKMENISTAN
TURKEY
Antalya
Sivas
GREECE
TUNISIA
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CRETE
CYPRUS
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Mediterranean Sea
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QATAR
Greatest eclipse
SAUDI ARABIA
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NIGER
Arabian Sea
OMAN
CHAD
SUDAN
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ETHIOPIA

FRED ESPENAK/*ASTRONOMY*: ROEN KELLY

TOTALITY WILL OCCUR over the Sahara Desert at the western part of Libya. This map shows the path of the Moon's shadow crossing Earth.

for cloudiness increases from southern Turkey to Georgia's coast. Mountainous terrain causes air masses to rise and condense, so weather patterns can be unstable.

Near Turkey's northern coast, the Moon's shadow intersects the path of the August 11, 1999 total eclipse. Some 250,000 people in Sivas will witness their second total eclipse in less than 7 years.

Black Sea and beyond

At 11h10m UT, totality reaches the Black Sea. As the darkness undulates over the waves and begins its journey into Georgia, weather conditions may worsen and temperatures can dip below freezing. Even on the northern Turkish coast, there is a slight possibility of snow.

/// NASA'S 2006 SOLAR ECLIPSE BULLETIN

Fred Espenak and Canadian meteorologist Jay Anderson have published a NASA bulletin for the 2006 total solar eclipse. The 74-page publication contains detailed predictions, tables, maps, and weather prospects for many locations.

Single copies are available free by sending a 9-by-12-inch self-addressed envelope stamped with sufficient postage for 12 ounces (340 grams) and with "TSE 2006" printed in the lower-left corner.

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The 2006 bulletin also is available in PDF format at: sunearth.gsfc.nasa.gov/eclipse/SEpubs/TP212762.html. Additional information, updates, maps, and diagrams are available at NASA's official 2006 total solar eclipse web site: sunearth.gsfc.nasa.gov/eclipse/SEmono/TSE2006/TSE2006.html. — *F. E.*

After 6 minutes over the Black Sea, the Moon's shadow continues to move through winter weather as the umbra brushes Georgia's western shore. It crosses the Caucasus Mountains, and proceeds into Russia and Kazakhstan, casting its temporary night over the region. Frigid temperatures will bring a greater possibility of clear skies, as well as the difficulty of ensuring that electronic equipment will function properly.

In the last minutes of contact with Earth, the shadow accelerates across central Asia and the observing window rapidly shrinks. The Moon's shadow swiftly swings off into space at sunset near Mongolia's northern border at 11h48m UT, ending its 3-hour journey.

Once again in the Sun

As the shadow leaves observers squinting in the sunshine, they will turn to each other with a sigh and say, "When's the next one?" As eclipse veterans know, the euphoria of viewing a total eclipse is much too brief. ■

ONLINE EXTRA When will an eclipse occur near you? Find out at www.astronomy.com/toc

In 1995, Hale-Bopp became history's most observed comet.
Ten years later, **Alan Hale** tells its tale.

Hale-Bopp +10

When Comet Hale-Bopp cruised overhead 10 years ago, astronomers and non-astronomers alike were thrilled by the dazzling view. Here's the story of how Thomas Bopp and I discovered this once-in-a-lifetime spectacle long before we could see it with the naked eye.

Amateur astronomers eagerly awaited Hale-Bopp to reach its brightest. At that point, we all saw cometary details — including a central region that resembled a water sprinkler — never before seen in small telescopes.

Casual and advanced astrophotographers remember Hale-Bopp as a bright, nearly irresistible target — the last great astronomical object recorded primarily on photographic film.

Casual observers remember Hale-Bopp as something they could see easily and at a reasonable time — this alone made its appearance more culturally relevant than other celestial events deemed important by astronomers, such as a solar eclipse over Africa or a 4 A.M. grouping of bright planets. Usually, only handfuls of dedicated amateur astronomers view such events. Billions of people saw Hale-Bopp. So, until a better comet comes along, it remains the great comet of our lives.

A comet discovered

Saturday night, July 22, 1995, looked to be exceptionally clear in the Sacramento Mountains of southern New Mexico. Indeed, it was the first clear night after more than a week of daily rain showers. After dark, I began my regular comet-observing program.

Shortly after midnight, while waiting for one of my chosen comets to rise into view, I observed some deep-sky objects. One was the globular star cluster M70 in Sagittarius.

Upon turning my telescope to M70, I noticed a diffuse 11th-magnitude object in the same field. Within an hour — during which time I verified that no known objects were in that position — I observed this object moving slowly against the background stars. As hard as it was to believe, I had stumbled across a new comet.

Meanwhile, a similar story was being played out in the desert south of Phoenix. Amateur astronomers had headed out that night for some dark-site, deep-sky observing. While observing M70, Tom Bopp, one of those present, noticed the same diffuse object I had seen. He ran through the same basic checks I had, and within an hour he also had detected motion.

That comet — assigned the designation C/1995 O1 and given the name Hale-Bopp — would prove to be no ordinary comet. Professional astronomers soon determined it was located at the enormous distance of 7 astronomical units (AU) from the Sun.

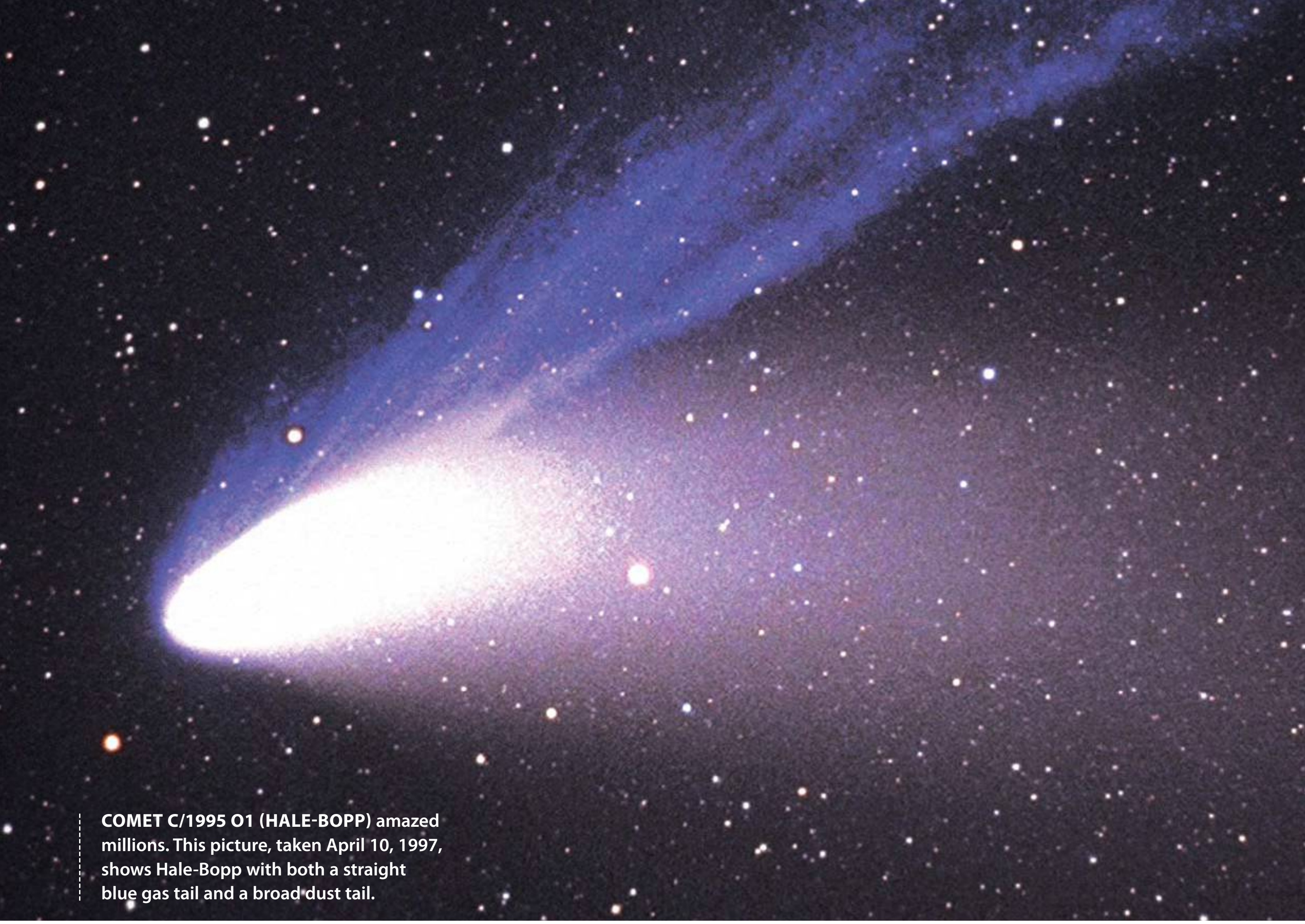
MICHAEL STECKER

EUROPEAN SOUTHERN OBSERVATORY

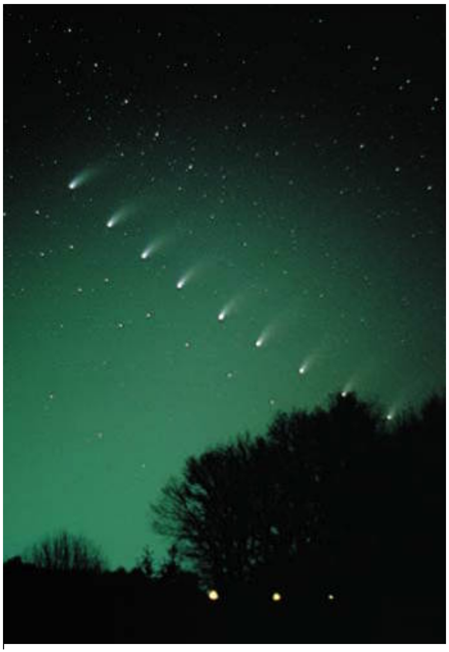
FOUR YEARS AFTER PERIHELION, Hale-Bopp still shows activity when imaged through a large telescope. The wide, fan-shaped tail extends 1.25 million miles (2 million km) to the upper left.

IN THE MOUNTAINS outside Genova, Italy, Hale-Bopp created spectacular panoramas.

ANDREA PERO



COMET C/1995 O1 (HALE-BOPP) amazed millions. This picture, taken April 10, 1997, shows Hale-Bopp with both a straight blue gas tail and a broad dust tail.



XAVIER LEPRETTE

ASTROPHOTOGRAPHERS created fascinating scenes with Hale-Bopp. This sequence — one shot every 15 minutes — shows the comet setting in France on March 31, 1997.

FRANS KLAUSER

AGAINST THE BACKDROP of the Milky Way in Cygnus, Hale-Bopp put on a show.

JAMIE GRANT

HALE-BOPP was a great comet because it was visible even from well-lit urban settings.

(One AU is the distance between Earth and the Sun — 93,000,000 miles.) At this distance, most comets aren't detectable for high-powered instruments, let alone being visible in moderate-size telescopes.

Brightening

Next came the most startling news of all: The comet was more than a year and a half away from perihelion, its closest point to the Sun. That wouldn't happen until April 1, 1997, when C/1995 O1 would be slightly less than 1 AU from the Sun. Although comets are famous for being unpredictable, all the ingredients for a "great comet" display seemingly were present.

During the year and a half leading to the comet's arrival, scientific interest in the comet grew. By the end of 1995, observations with the Hubble Space Telescope and other instruments indicated an unusual amount of activity in Hale-Bopp's central coma, and for good reason: The comet had one of the largest comae ever seen.

A year before Hale-Bopp would put on a show, public interest also grew because of a briefly seen but brilliant comet — C/1996 B2 (Hyakutake). Hyakutake was visible in March 1996. At its brightest, this comet displayed colors ranging from greenish-blue to purple. Its tail stretched more than halfway across the sky.

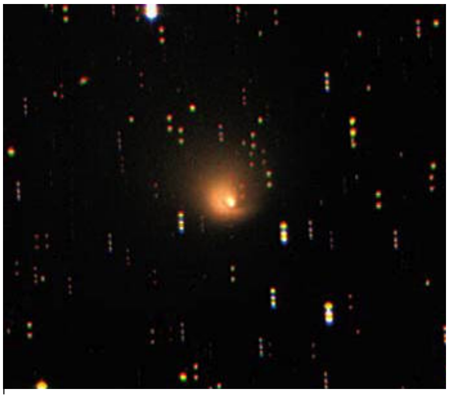
After solar conjunction (when Hale-Bopp was behind the Sun), the comet reappeared in the morning sky in early 1996. By June, it had brightened enough to be visible with the naked eye. The comet continued brightening throughout 1996, and was slightly brighter than 4th magnitude when it neared a second solar conjunction at year's end.

Observers remember Hale-Bopp's grand showing during the first few months of 1997. At first, it was a pre-dawn object. By late March, however, it had moved into the northwestern evening sky — a prominent object visible during "prime time."

Prime time

The comet peaked in brightness at magnitude –1 during late March and early April. Hale-Bopp exhibited both a prominent, curved dust tail and a structured straight ion tail, each about 20° long. (A closed fist held at arm's length spans 10°.) The comet was bright enough to be viewed even from light-polluted metropolitan areas, and was spectacular when seen from dark rural sites. It's fair to say more people saw Hale-Bopp than any other comet in history.

Alan Hale *is co-discoverer of C/1995 O1 (Hale-Bopp) and author of* Everybody's Comet, *published by High-Lonesome Books.*


EUROPEAN SOUTHERN OBSERVATORY

HALE-BOPP still could be seen with large telescopes years after its close approach to the Sun. This composite of images taken from February 27 to March 2, 2001, surprised astronomers, who expected to see only a quiescent ball of ice. At the time, Hale-Bopp was nearly 1.25 billion miles (2 billion kilometers) from the Sun.

Cultural comet

From a popular perspective, the comet was a big hit, practically a cultural icon. References to Hale-Bopp found their way into songs, movies, and television programs. It also was discussed at length in the popular media. Both Tom and I found ourselves much-sought-after "celebrities." In addition to being on the national — and even international — lecture circuit, we were featured in such diverse publications as *National Geographic* and *People* magazine.

Some interest in the comet was not all positive. For example, the unfortunate business of the "Saturn-like companion" stirred plenty of fear and controversy. The comet's arrival also led to the Heaven's Gate tragedy — when 39 cult members took their lives because they believed Hale-Bopp was the sign for them to shed their earthly bodies. For the most part, though, I believe Hale-Bopp helped us all become closer connected to our surrounding universe.

But no matter how spectacular the show and how delightful the time was for the comet's discoverers, it couldn't last forever. After perihelion, Hale-Bopp receded from both the Sun and Earth, and also began moving southward. It was lost to Northern Hemisphere observers in May 1997. At that time, Southern Hemisphere observers could observe it, still a relatively bright 2nd-magnitude object.

Scientifically, the comet was a bonanza, due both to its impressive performance and to the long lead-time provided by its early discovery. Much of the science concerning

/// MOVING FORWARD

Time marches on in my life. My older son — 8 at the time of the discovery — will graduate from high school this year. Last year, I fulfilled a lifelong fantasy when I began hosting my own program on a local radio station.

I continue to develop the educational and research organization I founded a couple of years before the discovery. In 2000, as a result of grants and equipment donations, I was able to start an astrometric program for comets and near-Earth asteroids.

I'm also active in what I call "science diplomacy." This activity carries me to interesting places throughout the world, including Iran twice (see photo at right), to interact with fellow scientists.

I'm developing a project called Earthrise — an endeavor to develop an interconnected global network of astronomical educational and research centers — that merges my educational and research work with my science diplomacy activities.

DOUG BIESECKER

ALAN HALE (right) traveled to Hamadan, Iran, in August 1999. To his right is Stacy Heen of Search for Common Ground. A school group poses with the pair at the "Stone Lion."

And, yes, I still spend quite a few clear nights out under the stars chasing comets and other objects. Sometimes I wonder about the world that will greet Hale-Bopp on its next return in the 44th century (according to latest calculations). — *A. H.*

JOHN CHUMACK

HALE-BOPP IMAGES benefited from the comet's brightness. This photo, taken at Natural Bridges National Monument in Utah, showed how bright Hale-Bopp was even when near the horizon.

Hale-Bopp was tied into questions of our own origins. The comet helped establish connections between material present in interstellar clouds and material delivered by comets to the early Earth.

Recessional

After conjunction, the comet made a brief encore appearance for the Northern Hemisphere during late 1997. At that time, it was located deep in the southern sky and had faded to magnitude 6. My last sighting of Hale-Bopp from New Mexico came the morning of November 18, 1997, from the top of an 8,000-foot ridge a few miles from my house. I watched it for an hour as it crawled all of 1° above the southern horizon and then set. Following this it dropped below our horizon permanently and entered the sky near the South Celestial Pole, where it remains to this day.

Southern-Hemisphere astronomers monitor it periodically. My last view of the comet occurred from Australia in late May 1998. At 9th magnitude, Hale-Bopp was still an easy binocular object. Amateur astronomers followed it visually until the first half of 2000. Larger telescopes still keep track of it from time to time.

The comet remains active, despite its ever-increasing distance from the inner solar system. An observation in January 2005 with the 6.5-meter Clay Telescope at the Magellan Observatory in Las Campanas, Chile, showed Hale-Bopp as a magnitude 20 object. Amazingly, Hale-Bopp still exhibits a distinct tail despite being 21 AU from the Sun.

As the comet recedes, the lives of its two discoverers have returned to normal — for the most part. It's fair to say our lives were changed irrevocably by the appearance of this wanderer from the outer solar system.

We now know more about comets and the role they've played in our past than we knew 10 years ago. This is, in part, due to Hale-Bopp and other bright comets that have appeared since then, as well as to spacecraft missions like Deep Space 1, Stardust, and the recently launched Rosetta and Deep Impact missions.

Automated sky-survey programs like the Lincoln Near Earth Asteroid Research (LINEAR) project based in New Mexico scour the skies and discover comets. It's unlikely another bright comet like Hale-Bopp could sneak up on us without being detected when still distant. Discoveries by the SOHO spacecraft tell us the number of comets entering the inner solar system is much higher than we once thought. These and other developments ensure our knowledge of comets will grow.

In the future, many comets will appear and vanish. Few will become visible to the naked eye. Certainly for Thomas Bopp and myself, no comet ever will be as special as Hale-Bopp. And during the past 10 years, I've come to understand the same holds true for many of you. A

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Dr. Goodman is exactly the guide you want on this tour—he is clear but comprehensive, objective but humane, learned but light-hearted. He received his undergraduate degree from Harvard University and his Medical Doctorate from Cornell Medical College. He completed his surgical training and Chief Residency at the Harvard Surgical Service of Boston City Hospital. Dr. Goodman is a Fellow of the American College of Surgeons and a Diplomate of the American Board of Surgery. Currently, he teaches gross anatomy in the W.W.A.M.I. Medical Sciences Program at Montana State University.

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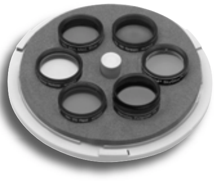

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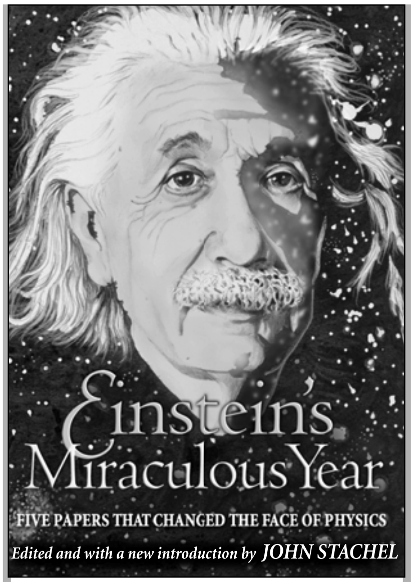

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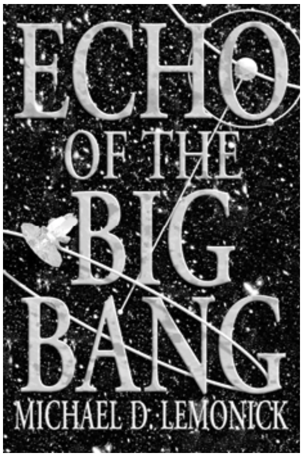

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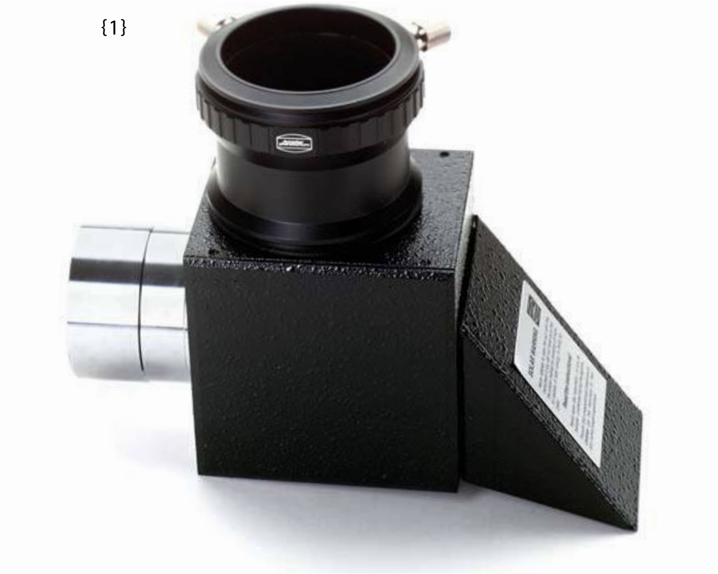

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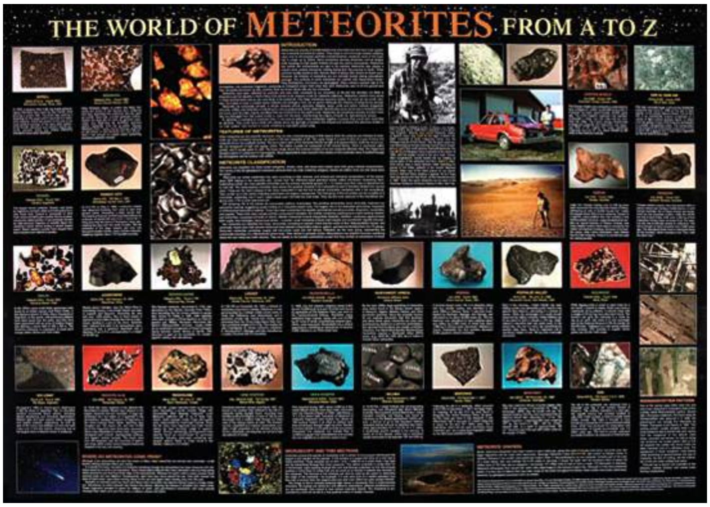

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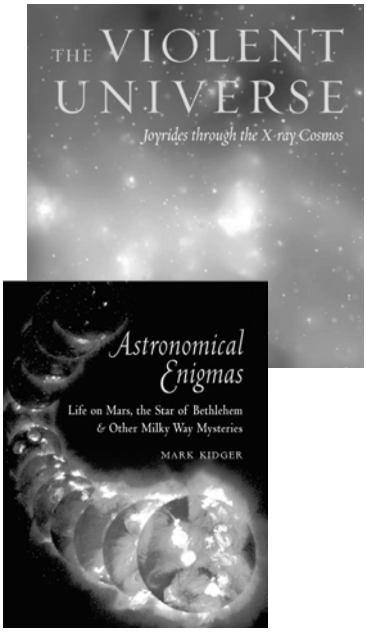
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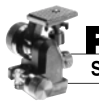

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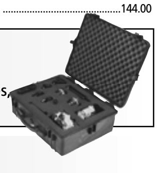

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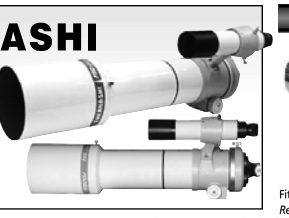

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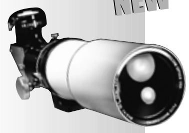

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Fits onto most 1.25" eyepieces *(with Removable Eyeguards)* and allows you to attach it to a Digital Camera (Requires a Digital Camera Adapter to connect to your digital camera)

Item	Price
Digi-T Ring for 1.25" eyepieces	29.95
Digi-T Ring Large for 1.25" eyepieces	29.95
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allows you to connect your camera direct to a telescope (requires a z-Adapter) Digital Camera AdapteruTO FIT Cameras with 28/37/49/52/58/62mm filter threads........................ 24.95

Uni-T Adapter

Universal Eyepiece to T-Adapter for Spotting Scopes..34.95

Uni-Adapt Universal

Eyepiece to T-Adapter. (fits eyepieces from just under .97" to 2 1/16 ") 164.95

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75 SDHF Refactor
500mm f6.7
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100 SDUF II
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Item	Price
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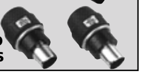

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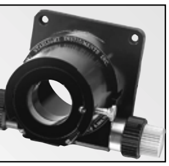
Starlight Instrument



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85mm APO 600mm f/7 Green Tube Kit #GXC-3370	2080.00
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60mm APO f/6,360mm Black Tube TVO-2460	795.00

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Item	Price
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Walnut Panoramic Mount	660.00
Walnut Gibraltar Mount	770.00
Ashwood Panoramic Mount	540.00
Ashwood Gibraltar Mount	660.00

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Item	Price
55mm 2"	228.00
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40mm, 32mm 1.25"	110.00
15mm, 11mm, 8mm 1.25"	82.00

PANOPTIC EYEPIECES

Item	Price
41mm 2"	495.00
24mm 1.25"	295.00
15mm 1.25"	210.00
35mm 2"	365.00
22mm 2"/1.25"	280.00
27mm 2"	330.00
19mm 1.25"	240.00

NAGLER EYEPIECES

Item	Price
31mm 2"	620.00
20mm 2"	440.00
13mm 1.25	280.00
9mm 1.25	280.00
3.5mm 1.25"	280.00
2mm-4mm Zoom	395.00
26mm 2"	580.00
17mm 2"	385.00
12mm 2"/1.25"	355.00
7mm 1.25" Type 6	280.00
2.5mm 1.25"	280.00
22mm 2"	460.00
16mm 1.25"	320.00
11mm 1.25"	280.00
5mm 1.25"	280.00
3mm-6mm Zoom	380.00

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Item	Price
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2" NebuStar Filter	215.00
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1¼" NebuStar Filter	125.00

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Item	Price
18mm, 14mm, 12mm, 10mm, 8mm, 6mm, 5mm, 4mm, 3mm	240.00

ZOOM EYEPIECES

Item	Price
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Item	Price
2" Enhanced Diagonal	210.00
1.25" Enhanced Diagonal	140.00
2" Everbrite Diagonal	275.00
1.25" Everbrite Diagonal	190.00

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Item	Price
Starbeam	205.00
Bino-Vue	1030.00

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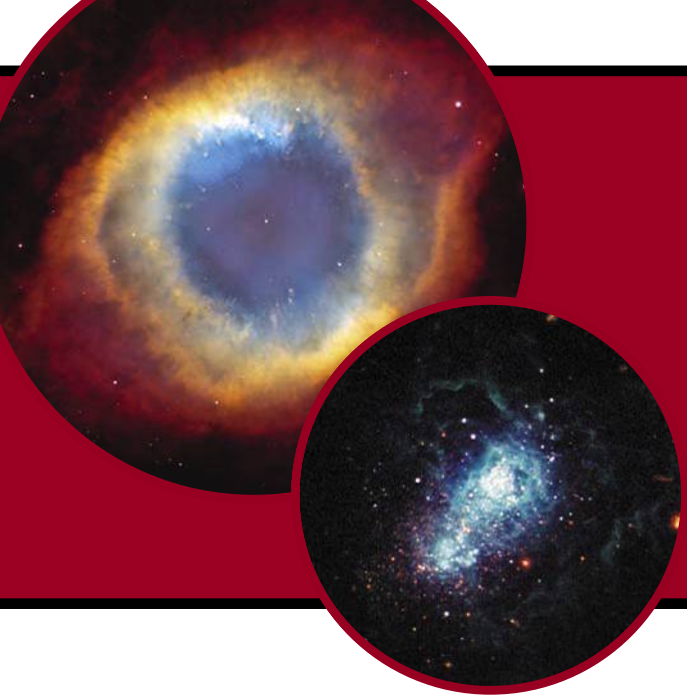

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astronomics . . . our 26th year.

We've been helping people choose the right telescope since 1979. We have the experience (a staff total of over 150 years of experience in using and selling telescopes) to help *you* pick the telescope that fits your needs (and your budget) from the hundreds of telescopes we stock. And, with our seven-figure inventory, we can usually ship you the right scope right away.

We started ***astronomics*** over 25 years ago because we loved astronomy, not just as a business. Our sales may have grown over a thousand-fold since that first year, but we're still the same family-owned, family-run, full-line telescope dealer we were in 1979. And we still love astronomy.

astronomics*.* No hard sell. No guesswork. Just honest advice, the time to make sure you get the right telescope and accessories, and a good price. Call us toll free at (800) 422-7876 and find out for yourself.

The newest Celestron CPC Schmidt-Cassegrains.

$1899

Celestron 8" f/10 CPC800

You don't need to know Alkaid from Algol to align a **Celestron CPC** scope on the sky. Just point a CPC at any three of the 50 brightest lights in the sky (3 stars, or 2 stars and a planet, but no UFOs or airplanes), and the CPC will find over 45,000 deep space objects for you at the touch of a button.

You don't have to memorize a star chart to set up a CPC scope. The built-in GPS system and a few anonymous points of light in the sky are all you need.

Celestron CPC Schmidt-Cassegrains are available in the following sizes:

8" **CPC800**, Starbright coatings	**$1899⁰⁰**
8" **CPC800X**, XLT coatings	**1999⁰⁰**
9¼" **CPC925**, Starbright coatings	**2349⁰⁰**
9¼" **CPC925X**, XLT coatings	**2499⁰⁰**
11" **CPC1100**, Starbright coatings	**2599⁰⁰**
11" **CPC1100X**, XLT coatings	**2799⁰⁰**

Each has all the visual and photographic features you want and need, plus Celestron's best multi-coated optics ever.

Celestron snaps the solar system for $99.

$99

PREMIER SELECT CELESTRON DEALER

There's a real color CCD camera in the **Celestron NexImage** Solar System Imager. It's a Sony HAD (Hole Accumulation Diode) full color CCD with 640 x 480 5.4 micron pixels.

The NexImage takes high power Moon and planet images with any scope and sends them to your computer to view live or print out later.

Would you buy a telescope from this man?

In 18 or 20 years you might be doing just that.

Say hello to Liam, the third *astronomics* generation and its future CEO. Born 11/22/04, he'll soon be helping his father, mother, grandfather, and grandmother run the company.

Celestron 11" scopes start at only $1699.

$1699

11" Celestron C11S

With almost twice the light-gathering of an 8" scope, **Celestron Advanced Series** 11" German equatorial mount Schmidt-Cassegrains show you more deep space wonders than an 8" SCT on a fork mount – *for about the same price.*

The 11" Advanced Series telescopes available from our stock include:

C11S on German equatorial mount	**$1699⁰⁰**
C11S with XLT coatings	**1979⁰⁰**
C11S-GT go-to German equatorial	**1999⁰⁰**
C11S-GT go-to with XLT coatings	**2279⁰⁰**

The C11S and C11S (XLT) have a heavy-duty equatorial mount, adjustable height tripod with 2" steel legs, slow motion controls, setting circles, a 40mm Plössl eyepiece, and a 9 x 50mm finder. Starbright multicoated optics are standard on the C11S. The state-of-the-art Starbright XLT multi-coatings on the C11S (XLT) give you an extra 16% light transmission for even brighter deep space images. An optional dual-axis drive is available.

The C11S-GT and C11S-GT (XLT) go-to models add dual motor drives and a NexStar computer that automatically finds and tracks over 45,000 stars and objects for you.

At only 29 lbs. for the heaviest component, each is easy to transport and set up. And, best of all, they are *all* very affordable. A big telescope no longer costs a fortune, thanks to Celestron.

A Telegizmos helps your scope keep its cool.

$56

The Telegizmos for a 4" refractor

Telegizmos scope covers protect your scopes from the sun and dew at star parties and in your backyard. Originally developed for NASA as a spacecraft insulator, the aluminized multi-layer Telegizmos cover is strong, light, tear and puncture resistant, and much more durable than Mylar.

Prices start at only $29 for an ETX scope cover. A cover for an 8" SCT costs only $49. Even the cover for an 18" truss tube Dob costs only $68.

We have extended hours for your convenience at *astronomics . . .*

Our phone lines are open until 9 PM CST weeknights. You can call late and still get the friendly, reliable Astronomics service you've trusted for over 25 years. Our telescope experts are ready to help – so you can call us late for all your telescope needs!

Meade brings space optics down to Earth.

$6599

Meade 12" f/8 RCX400 Ritchey-Chrétien

The **Meade** 10" through 16" modified Ritchey-Chrétien telescopes put virtually the same premium optical design used in the Hubble Space Telescope into affordable and portable telescopes for amateur astronomers. With a wide coma-free field for astrophotography, Ritchey-Chrétiens are the telescope of choice in many professional observatories.

The big and fast f/8 Meade Ritchey-Chrétiens are available in four sizes:

The 10" **RCX400 10"**	**$4999⁰⁰**
The 12" **RCX400 12"**	**6599⁰⁰**
The 14" **RCX400 14"**	**8999⁰⁰**
The 16" **RCX400 16"**	**15,999⁰⁰**

Each adds a full aperture correcting lens to the R-C design to reduce residual astigmatism so stars stay point-like across the entire field. Level North Technology and GPS make aligning on the sky *automatic.* You start observing in minutes. Standard equipment UHTC optics for a 15% increase in light transmission, High Precision Pointing, Permanent Periodic Error Correction, a 2" UHTC star diagonal, and a 2" 24mm Ultra Wide eyepiece – the list of features just goes on and on.

No-guesswork Celestron SLT go-to scopes start at $249.

$339

80mm Celestron NexStar 80 SLT

You don't need to know the stars from Aldebaran to Zubenelgenubi to find your way around the sky with a **Celestron SLT** computerized telescope. With Celestron's no-guesswork SkyAlign technology, you just point your Celestron SLT at any three of the 50 brightest lights in the sky (3 stars, or 2 stars and a planet, but no UFOs or moving airplanes, please), and the scope will find over 4,000 deep space objects for you *automatically.* A few anonymous points of light are all you need to find your way around the sky like a pro.

Celestron SLT no-guesswork scopes are available in the following sizes:

NexStar 60, 60mm refractor	**$249⁰⁰**
NexStar 80, 80mm refractor	**339⁰⁰**
NexStar 102, 102mm refractor	**419⁰⁰**
NexStar 114, 114mm reflector	**379⁰⁰**
NexStar 130, 130mm reflector	**399⁰⁰**

Each is complete with two eyepieces, a Star Pointer red dot finder, motor drives, stainless steel tripod, NexStar computer, software to control the scope from your home computer, and more.

A best-selling William Optics semi-apo for only $399.

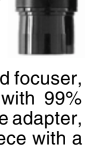
$399

William Optics ZenithStar 80mm semi-apo optical tube

The **William Optics ZenithStar 80** is such a great value that we have trouble keeping it in stock. Some dealers might say that and be telling you a story, but it's true with us. We get these scopes in 20 at a time and ship them out to waiting customers almost immediately.

The ZenithStar 80 semi-apochromatic doublet costs only **$399**. It has an 80mm multicoated f/6 optical system with a fully rotatable 2" Crayford-style focuser, a 1.25" eyepiece adapter, retractable self-storing lens shade, dust caps, and a fitted soft carry bag. Its removable L-shaped mounting shoe will let you mount it on a photo tripod or on a Schmidt-Cassegrain piggyback. You can use it either as a super finder for your main telescope or as an optically excellent second scope for spur-of-the-moment astronomy, travel, or birding.

A bird in the hand looks great, if that bird is a Swan.



These Swan wide field eyepieces from **William Optics** won't ruffle your feathers – or your bank account.

The 9, 15, and 20mm 1.25" Swan eyepieces are $78 each. Each has a wide 72° field and sharp images. Equally sharp are the 25, 33, and 40mm 2" Swans at $118 each. They also have a wide 72° field (70° on the 40mm).

You can now get a passel of ED Backpackers.

Burgess SD101 4" f/5.5 Backpacker

$799

The new 65mm, 80mm, and 101mm Backpacker refractors from **Burgess Optical** use ED (extra low dispersion) glass doublets for color correction eight times better than a typical achromat. Add their superb mechanics and you have top-quality and very compact refractors at rock-bottom prices.

Take the 4" f/5.5 SD101 Backpacker, for example. It comes fully equipped with CNC-machined tube rings, a retractable lens shade, 2" rotating Crayford focuser, a 2" *dielectric* star diagonal with 99% reflectivity and a 1.25" eyepiece adapter, a 38mm Super Wide 2" eyepiece with a wide 70° field of view, and a fitted backpack carrying case.

Compare any of the Backpackers with competitive scopes. The quality optics, extreme portability, and amazingly low prices make these wide field ED Backpacker scopes an easy choice for anyone who wants a great all-around or travel scope at a truly affordable price.

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Meade 8" LX200 GPS
$2195

You can get the Meade telescope you want shipped from our stock . . . right now . . . at the right price . . . right here at ***astronomics.***

Meade LX200GPS telescopes have a GPS system to align your telescope on the sky *automatically.* You start observing in minutes.

They have feature-laden Autostar computers to find and track over 145,000 stars and objects for you *automatically.* You spend more of your time looking *at* heavenly bodies and less time looking *for* them.

Built-in Smart Mount Technology improves your LX200's pointing accuracy as you observe. A Lunar Pla mtary Imager tates igital color pictur s for you. Optional UHTC optics increase the light transmission by an average of 15%.

Here are the Meade LX200GPS telescopes that we ship from our stock via Fedex ground:

7" Maksutov-Casseg ain	$\$2695^{00}$
7" Maksutov-Cassegrain, w/UHTC	2845^{00}
8" Schmidt-Cassegrain	2195^{00}
8" Schmidt-Cassegrain, w/UHTC	2370^{00}
10" Schmidt-Cassegrain	2745^{00}
10" Schmidt-Cassegrain, w/UHTC	2980^{00}

Here are the scopes Meade ships from the factory via motor freight due to their weight:

12" Schmidt-Cassegrain	$\$3595^{00}$
12" Schmidt-Cassegrain, w/UHTC	3890^{00}
14" Schmidt-Cassegrain	4995^{00}
14" Schmidt-Cassegrain, w/UHTC	5345^{00}
New lower prices on all 16" models!	
16" SCT, w/altazimuth pier and UHTC	$\$10{,}639^{00}$
16" SCT, w/equatorial pier and UHTC	$10{,}894^{00}$

From $89 to $449 – Meade's new Series 5000 eyepieces.

Each of the twenty new **Meade Series 5000** eyepieces uses a unique five to seven lens optical system to give you a very wide field of view and long eye relief. Each has a convenient twist-up eyecup.

There are seven new 60° field Series 5000 Plössls; six new Super Wide Angles, each with a 68° field; and seven new Ultra Wide Angles, each with a huge 82° field.

MEADE
ELITE DEALER

$299 for a Meade Deep Sky Imager.

The **Meade ceep y Imager** takes color deep sky photos at a fraction the cost of a CCD camera. Use it with any scope to take photos of alaxies, nebulas, star clusters – plus the Moon and planets.

The easy-to-use Meade Deep Sky Imager also includes the Autostar Software Suite of planetarium and imaging control software in its low price of only $299.

Meade LXD75 go-to scopes make astronomy easy.

6" Meade N-6 AT Schmidt-Newtonian
$799

8" Meade SC-8 AT Schmidt-Cassegrain
$1299

Even if you're not familiar with the skies, you won't spend all of your time hunting for deep space wonders with a go-to computerized **Meade LXD75** reflector, refractor, or Schmidt-Cassegrain.

A few touches on the Autostar computer and your LXD-75 speeds you to any of more than 30,000 stars, planets, and deep space objects, then tracks it accurately for as long as you want to observe. You spend more of your time actually looking *at* celestial objects and less time looking *for* them with a Meade LXD75.

Each has an adjustable height steel leg tripod, battery-operated dual motors, finderscope, eyepiece, il minated polar finder, Autostar computer, and Lunar Planetary Imager color digital camera.

Want to read *unbiased* equipment reviews by astronomers just like you? Find them at
www.cloudynights.com

Meade LX90-LNT – brand new scope, same old price.

$1695

It's not often that you get a significant upgrade to a product without an equally significant price increase. But Meade has just done it with their new LX90-LNT.

The 8" **Meade LX90-LNT** Schmidt-Cassegrain has *Level North Technology* that makes aligning your scope on the sky easier than ever before. Simply tell the scope your zip code or location. The LX90-LNT levels its optical tube by itself, aims the tube north, sets the time, and moves to its first alignment star – *automatically!* Center the new red dot finder on the alignment stars (you get an 8 x 50mm finder, too), and start observing. It's almost as easy to use as a GPS system, but it costs no more than last year's LX90!

and we'll meet or beat any advertised price!

If you find a lower nationally advertised price on any in-stock product we sell, either in this magazine or on a telescope or camera store's website (chain stores excluded), let us know when you order. We'll meet or beat any delivered price.

We actually stock TeleVue. Does your dealer?

NP-101 **$3595**

Others may *say* they carry TeleVue, *but we actually keep TeleVue in stock.* Lots of it.

Here are a few of the TeleVue refractors that we have in stock for immediate shipment.

TV-60, 2.4" f/6 apo	$\$795^{00}$
TV-76, 3" f/6.3 apo	1275^{00}
TV-85, 3.35" f/7 apo	1680^{00}
TV-102, 4" f/8.6 apo	2200^{00}

These refractors are all basic optical tubes, with dust covers and carry case.

Complete optical tube packages, with a star diagonal, Plössl eyepiece, mounting ring, dust covers, and carry case are also available from stock.

As for accessories, we keep them all. Whatever you need – a mount; an eyepiece, be it a Nagler, Radian, Panoptic, or Plössl; a Powermate or Barlow; 99% reflectivity Everbrite dielectric star diagonal; light pollution filter; or more – if it's TeleVue, we probably have it in stock.

Scopebuggy makes it easy to move your scope.

$265

A **Scopebuggy** scope transporter is so efficient that the 6 year-old daughter of one of our customers moves her Dad's 14" Celestron CGE1400 all by herself.

Big 10" pneumatic tires, a pivoting front wheel, and a pull handle make it child's play to move telescopes weighing up to 300 lbs with the new Scopebuggy.

Celestron Dobs are nifty, inexpensive, *and in stock.*

8" f/6 StarHopper
$349

Celestron StarHopper Dobsonians use roller bearings for smooth hitch-free horizontal and vertical motion at the touch of a finger.

The 6" StarHopper comes standard with a 6 x 30mm finderscope, a 1.25" metal rack and pinion focuser, and a 25mm 1.25" Plössl eyepiece.

The 8", 10", and 12" StarHoppers each come with a big 9 x 50mm finderscope, a 2" metal rack and pinion focuser (with a 1.25" eyepiece adapter), and a 32mm E-Lux 2" eyepiece. The 10" and 12" scopes have a battery-operated fan for cooling their primary mirrors.

All scopes have fast cool-down metal tubes and BK7 optical glass mirrors.

We keep all the Celestron Dobsonians in stock for immediate shipment.

Here are the prices for the fully-equipped Celestron StarHopper Dobsonians.

6" f/8 StarHopper	$\$249^{00}$	+ $ 9 freight
8" f/6 StarHopper	349^{00}	+ $69 freight
10" f/5 StarHopper	499^{00}	+ $79 freight
12" f/5 StarHopper	849^{00}	+ $129 freight

Are these prices great? You bet they are.

$209

3.5" f/11 Konus refractor

8" f/5 Konus reflector
$519

$799

6" f/12 Konus Maksutov

The prices on these **Konus** telescopes are downright amazing.

Consider the 90mm **Konusmotor-90** f/11 refractor, left. It has a good equatorial mount with a battery-operated motor drive, *two* 1.25" Plössl eyepieces, and more – for only $209!

The **Konusky-200** 8" f/5 reflector, right, has a heavy duty equatorial mount with a steel leg tripod, *dual-axis* drives, two good 1.25" Plössl eyepieces, 8 x 50mm finderscope, a polar axis finder, and more. And it's only $519!

The **Motormax-150** 6" Maksutov, right, has the same heavy duty mount and accessories as the 8" reflector – but at a $799 price that's well below that of other Maks.

> Thanks for holding the scope for me. After calling many other places for this purchase, I'm confident I've found the best possible source for my astronomical needs.
>
> **Customer Quote of the Month #160**

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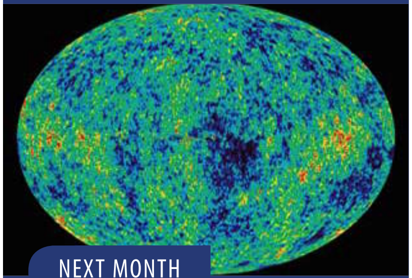
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JULY 31–AUGUST 5, 2005

The 12-year-old Nebraska Star Party (NSP) has established itself as one of the premier amateur astronomer gatherings. The main attraction is the site's dark sky — many attendees boast of a 7.5 limiting magnitude. ☾ While many similar star parties are geared for advanced skygazers, the NSP encourages novices to take part. Each day, a field school will teach beginners a new observing skill. Then during the evening, students will pair with experienced observers to practice what they've learned.

Outdoor activities will provide an alternative to observing. The NSP is held at Merritt Reservoir — one of Nebraska's top lakes. When not at the eyepiece, try swimming, boating, or fishing — the reservoir holds many state angler records.

For more information, call the NSP hotline at 402.489.8197; web site, www.nebraskastarparty.org.

ROBERT SWANSON

THE SUMMER MILKY WAY shines brightly above the NSP. As twilight approaches, the region will begin to reveal a treasure trove of targets for small scope observers.

JUNE 30–JULY 4

Stargazing Manitoulin

Gordon's Park, Manitoulin Island, Ontario. The site offers stargazing under the darkest skies in the region. Besides the typical star-party fare, attendees will be treated to nature activities. For more information, visit www.gordonspark.com.

JULY 1–4

Island Star Party

The Victoria Fish and Game Association site, near Victoria, British Columbia. Hosted by the Cowichan Valley StarFinders, this event features observing, lectures, and guided nature walks. For more information, call Frank Ogonoski at 250.748.5110; e-mail, c.v.starfinders@telus.net or richly@telus.net; web site, starfinders.cvnet.net/home.htm.

JULY 6–10

Green Bank Star Quest

National Radio Astronomy Observatory, Green Bank, West Virginia. Besides observing, activities will include imaging workshops, lectures from leading astronomers, activities for children, and exclusive tours of the Green Bank Telescope, the world's largest radio telescope. For more information, call 304.626.5012; web site, www.greenbankstarquest.org.

JULY 6–10

Shingletown Star Party

Shingletown Airport, Shingletown, California. Each year, veterans and novices of astronomy gather on the Shingletown Airport's runway for observing. Attendees also will find lectures, workshops, and vendors at this star party. For more information, visit www.shingletownstarparty.org.

JULY 6–10

White Mountains Astronomy Club Star Party

Mt. Bachelor Ski Area, near Bend, Oregon. From an elevation of 5,800 feet (1,787 meters), the site provides superior naked-eye seeing. This event features observing, workshops, nature talks, and door prizes. For more information, visit www.mbsp.org.

JULY 7–10

Rocky Mountain Star Stare

Pike National Forest, near Colorado Springs, Colorado. This event is sponsored by the Colorado Springs Astronomical Society. Workshops, lectures, and contests will be held during the day. For more information, visit www.rmss.org.

JULY 7–9

Starry Night, Prairie Night

Jeffers Petroglyphs Historic Site, Comfrey, Minnesota. This weekend combines observing, archaeology, and nature. Learn about nocturnal prairie animals, view petroglyphs at twilight, listen to folklore about Native American constellations, or gaze through the eyepiece of one of the many scopes on hand. Several astronomers will be present to answer your questions. For more information, visit www.jefferspetroglyphs.com.

JULY 8–10

Gateway to the Universe

Munro Park Family Campground, Powassan, Ontario. This family-oriented star party offers the darkest sky in Ontario. For more information, visit www.gatewaytotheuniverse.org.

JULY 8–10

RocheStar Fest

Wolk Observatory, Ionia, New York. Join the Rochester Astronomical Society for stargazing, talks, demonstrations, and workshops. The weekend will be capped with a cookout. The featured speaker will be *Astronomy* contributing editor Phil Harrington. For more information, visit www.rochesterastronomy.org.

JULY 9

Cuyahoga Astronomical Association Annual Convention

Letha House Park, Spencerville, Ohio. Although an annual gathering for the astronomical group, the general public is welcome. The daylong event will feature observing, lectures, workshops, and a potluck dinner. For more information, visit www.geocities.com/cuyastro.

JULY 23–24

National Optical Astronomy Observatory CCD Workshops

Tucson, Arizona. Join renowned astrophotographer Adam Block for workshops covering CCD-related topics from equipment to problem-solving to compressing images. For more information, call 520.318.8726; web site, www.noao.edu/outreach/kpvc.

JULY 30–AUGUST 7

Mt. Kobau Star Party

Mt. Kobau, near Osoyoos, British Columbia. The 22nd annual gathering will be held among the sagebrush and conifers of one of Canada's finest mountain sites for observing. Daytime activities will include workshops, lectures, and contests. For more information, e-mail, info@mksp.ca; web site, www.mksp.ca.

CONTACT INFORMATION

Please submit club announcements 4 months in advance to Coming Events, *Astronomy*, P. O. Box 1612, Waukesha, WI 53187, or jmcgovern@astronomy.com. Also use this e-mail address to submit your events for our on-line calendar.

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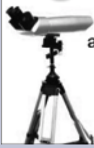

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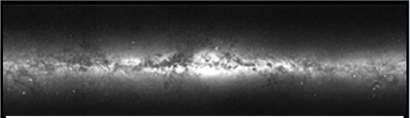

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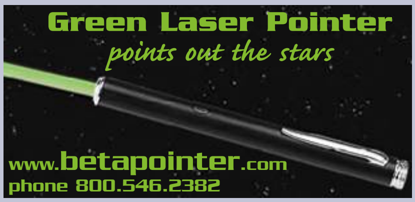
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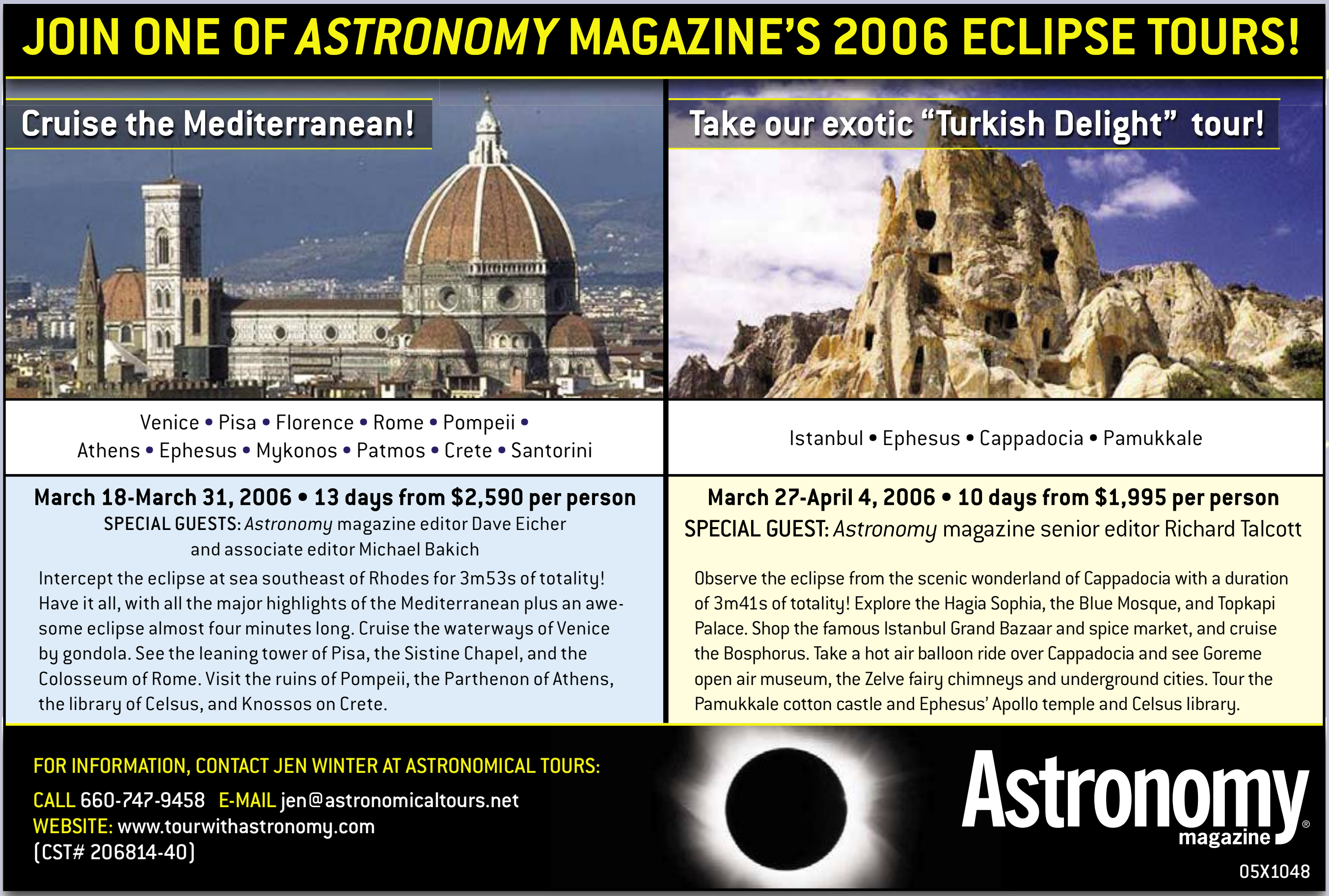
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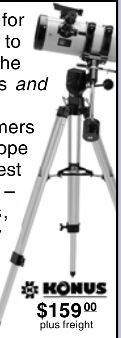

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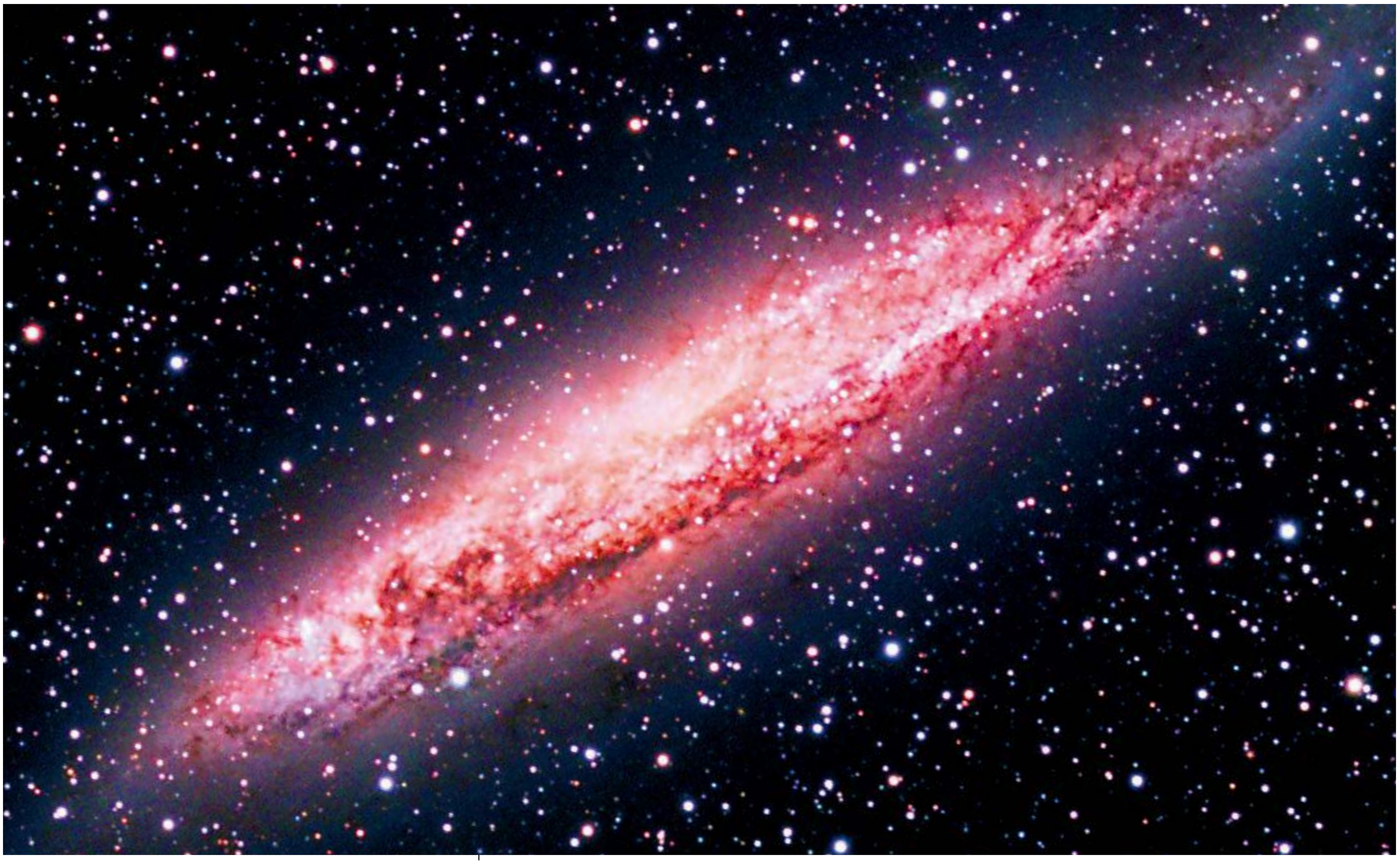
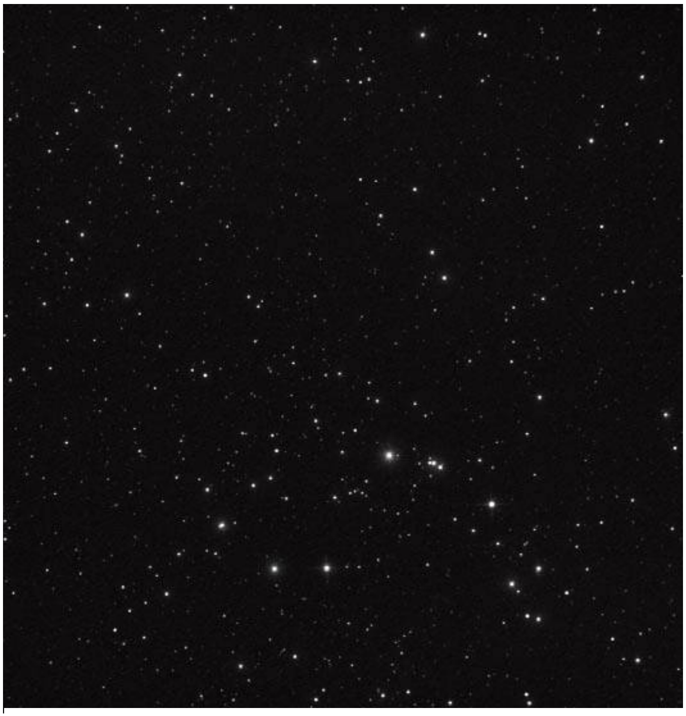


NGC 4945 (14.5-inch RC Optical Systems Ritchey-Chrétien telescope at f/6.56, an Astro-Physics AP1200GTO mount, SBIG ST-10XE CCD camera, Astrodon Tru-Balance filter set, LRGB image composite with exposures of 120, 60, 60, and 60 minutes, respectively) /// **DANIEL VERSCHATZE**

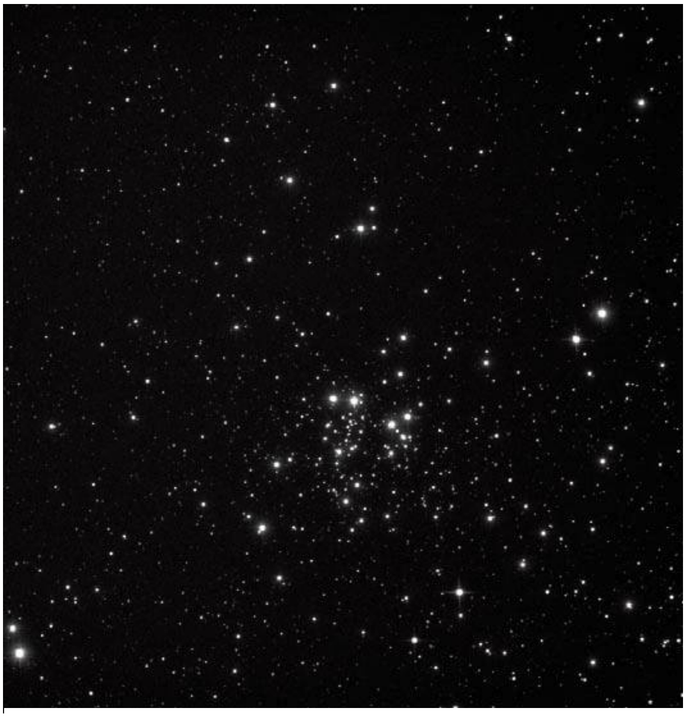
SOUTHERN BEAUTY

NGC 4945

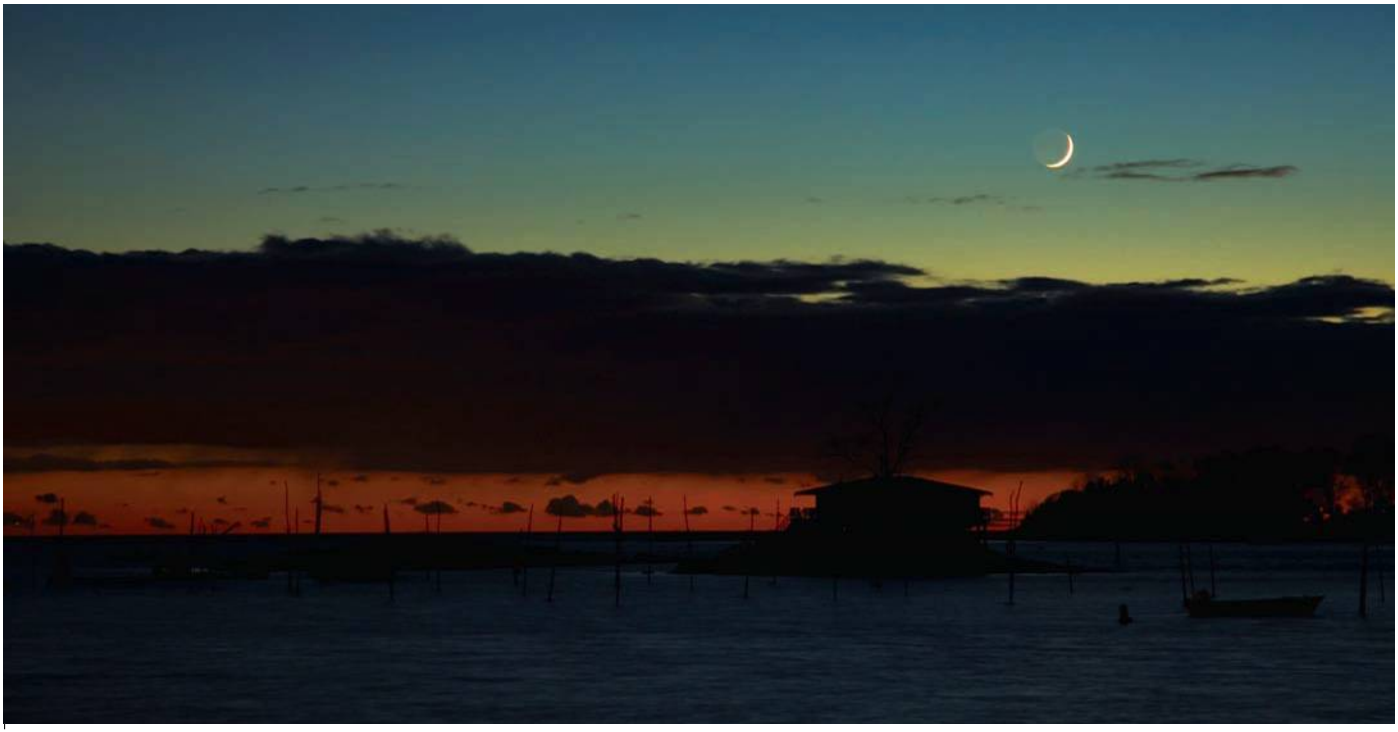
This beautiful but unusual spiral galaxy lies within the boundaries of the southern constellation Centaurus, so many northern observers have never seen it. Because of its edge-on orientation, many regions of NGC 4945 are shrouded in dust. This gives the galaxy its yellowish look and partly masks its spiral structure. Together with M83 and Centaurus A (NGC 5128), NGC 4945 forms part of a small group of galaxies 13 million light-years away.



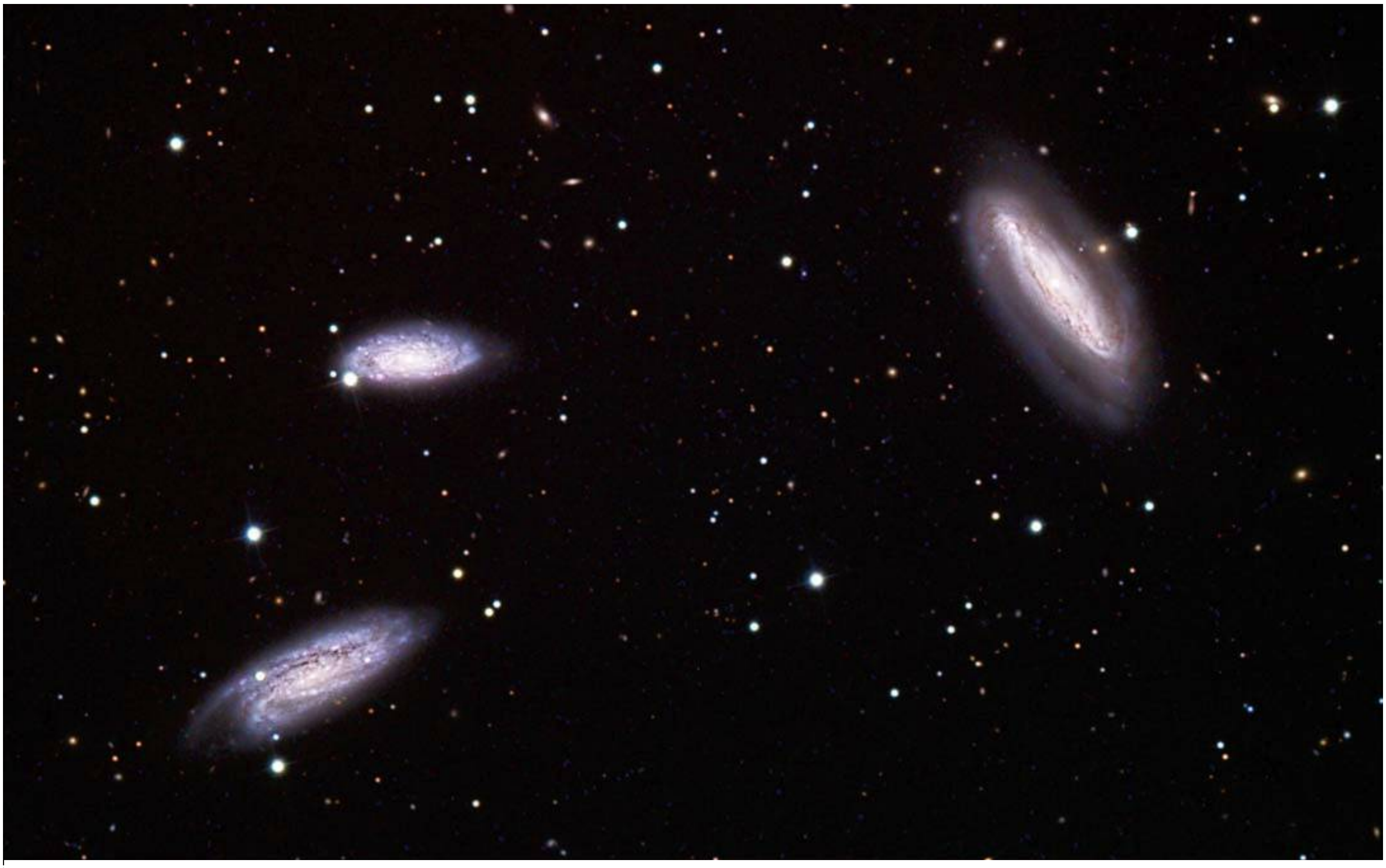
OPEN CLUSTER NGC 1582 IN PERSEUS (3.1-inch Stellarvue SV78-S apochromatic refractor, Starlight Xpress HX916 CCD camera, composite of thirty 30-second exposures) /// **ADAM STUART**



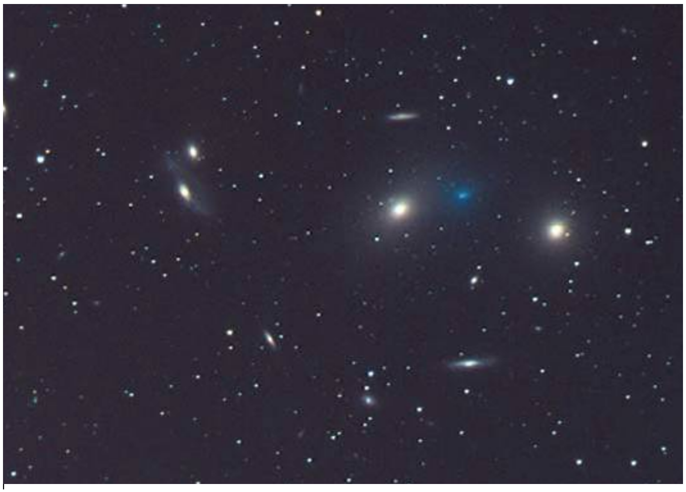
OPEN CLUSTER NGC 663 IN CASSIOPEIA (3.1-inch Stellarvue SV78-S apochromatic refractor, Starlight Xpress HX916 CCD camera, composite of thirty 30-second exposures) /// **ADAM STUART**



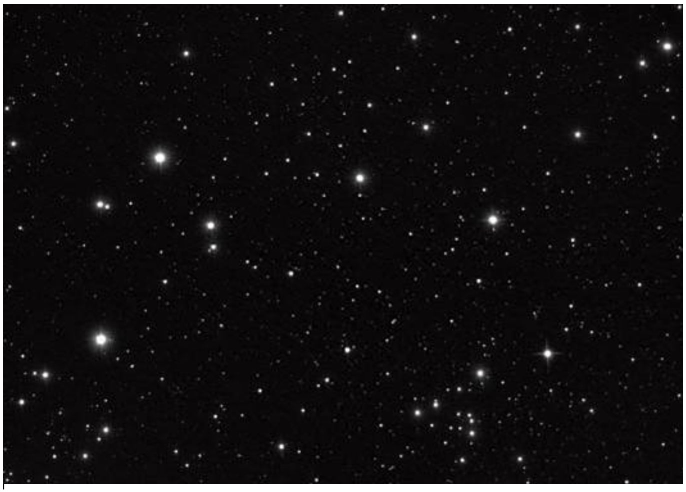
EARTHSHINE ON THE MOON (Nikon D70 digital camera, Nikkor 18-70mm lens set at 70mm and f/5, 2.5-second exposure taken December 13, 2004) /// **JIM McKAY**



SOUTHERN GALAXY TRIPLET (NGC 7582, NGC 7590, and NGC 7599; 14.5-inch RC Optical Systems Ritchey-Chrétien telescope at f/6.56, SBIG ST-10XE CCD camera, LRGB image with exposures of 90, 30, 40, and 60 minutes, respectively) /// **DANIEL VERSCHATSE**



COMET 62P/TSUCHINSHA in the Virgo Cluster (8-inch Schmidt, Starlight Xpress SXV-H9 CCD camera, RGB image with exposures of 240, 240, and 180 seconds, respectively, taken January 16, 2005) /// **MICHAEL JÄGER AND GERALD RHEMANN**



OPEN CLUSTER NGC 743 in Cassiopeia (3.1-inch Stellarvue SV78-S apochromatic refractor, Starlight Xpress HX916 CCD camera, composite of eighty 30-second exposures) /// **ADAM STUART**

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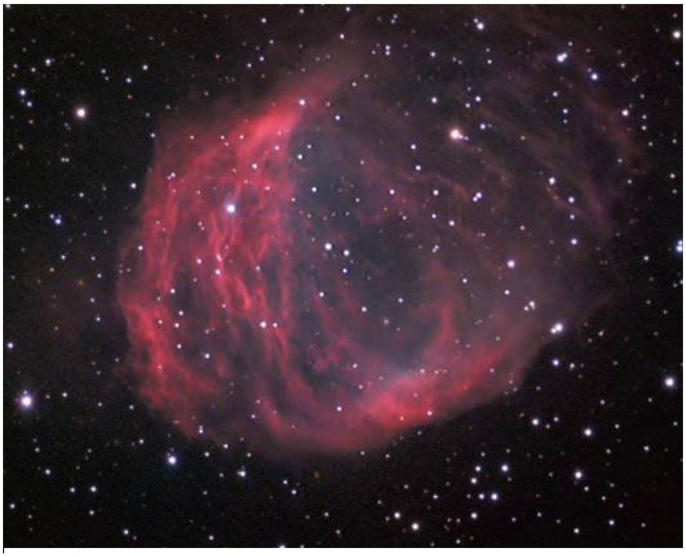
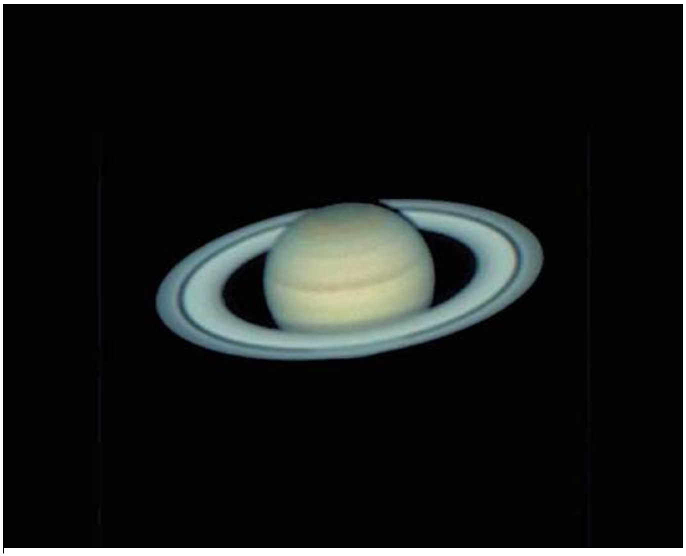
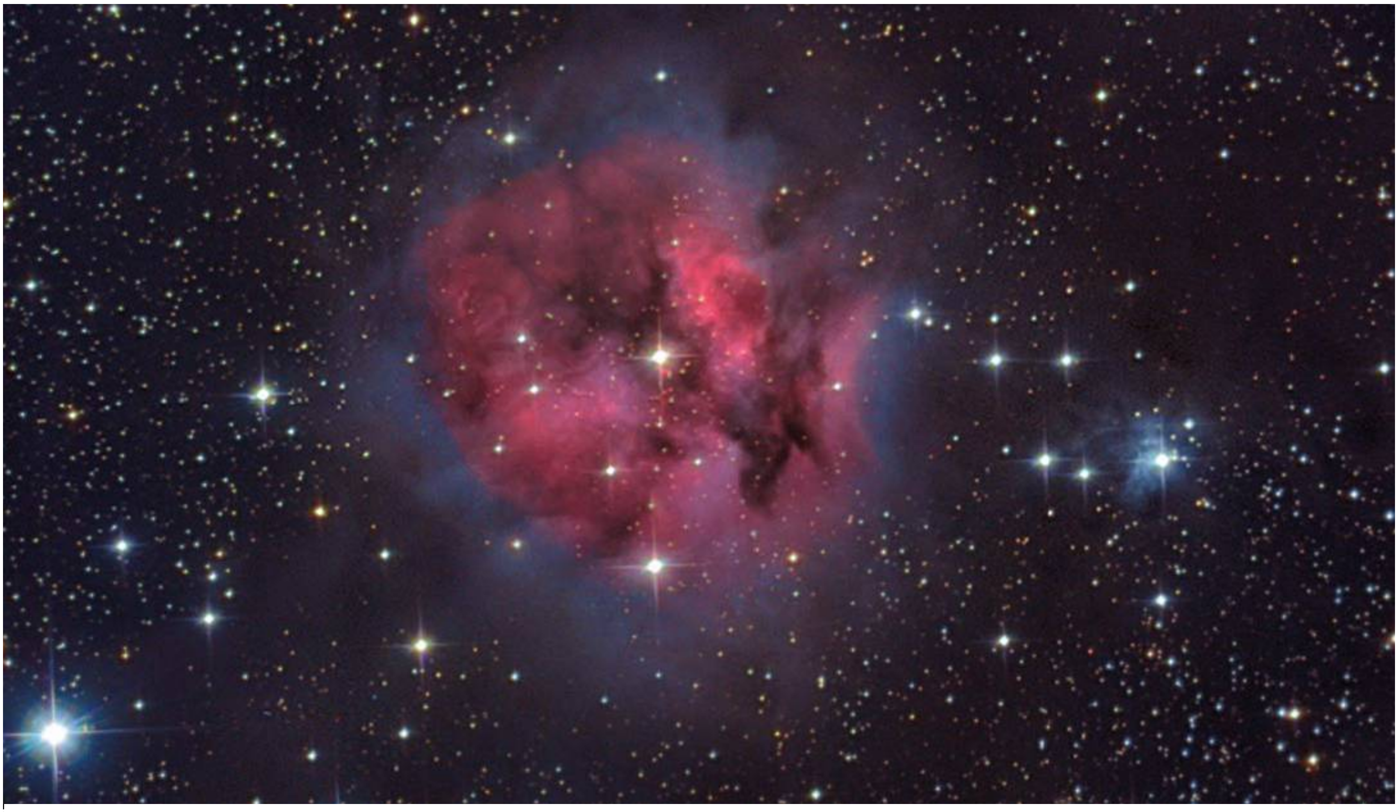


THE MEDUSA NEBULA (Abell 21) in Gemini (20-inch home-built Newtonian astrograph telescope using an SBIG STL-6303E CCD camera, HαHαRGB image composite with exposures of 100, 100, 50, 50, and 60 minutes, respectively) /// **BRIAN LULA**

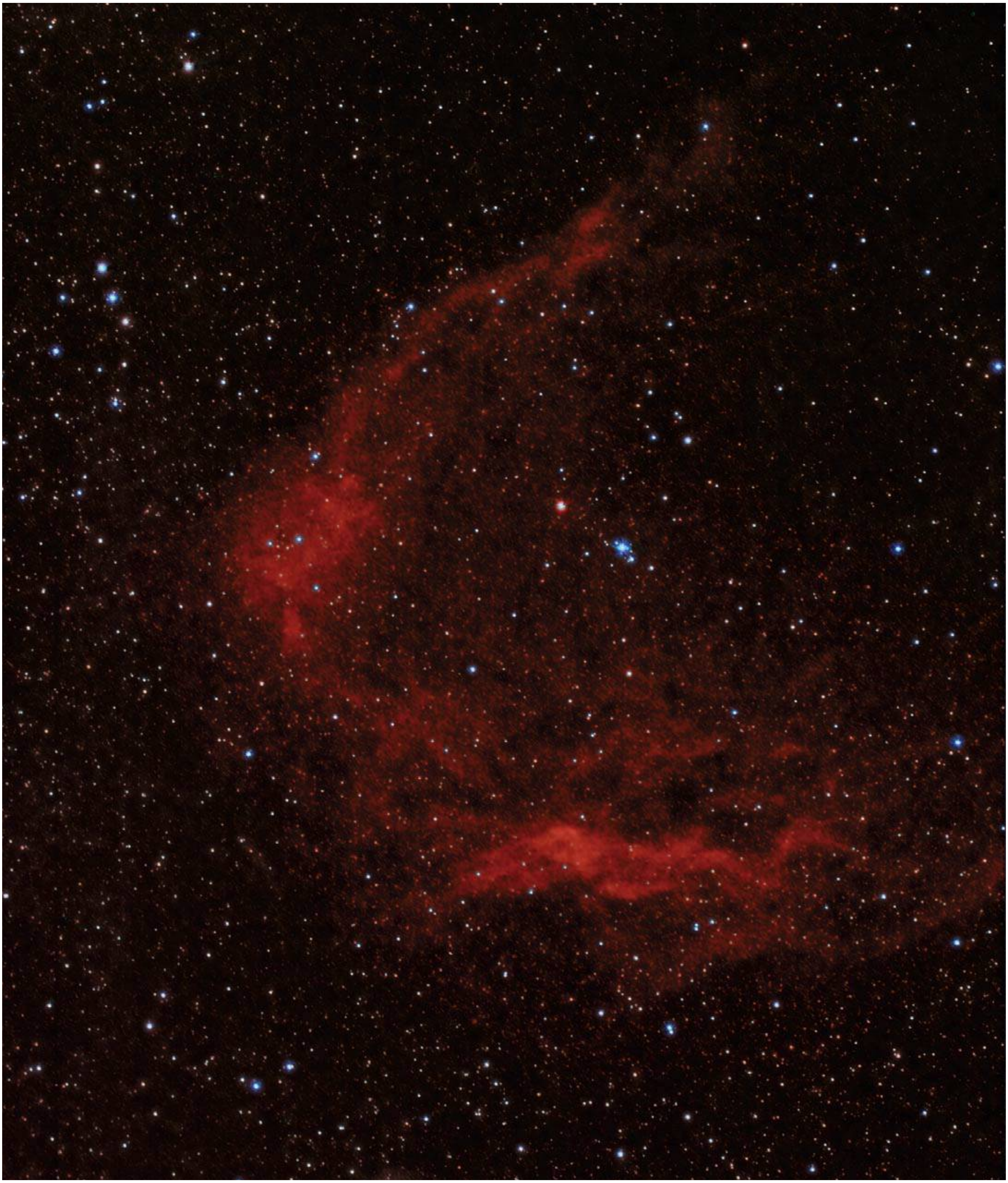


SATURN (8-inch TMB 203 apochromatic refractor at f/9 using an Atik Instruments ATK-2C color CCD camera, taken January 25, 2005, between 10:17 and 10:21 P.M. EST) /// **JIM PHILLIPS**



THE COCOON NEBULA (IC 5146) in Cygnus (13-inch Hypergraph Cassegrain telescope at f/3.1, Starlight Xpress SXV-H9 CCD camera, HαLRGB image with exposures of 1,920; 2,700; 1,920; 1,400; and 1,920 seconds, respectively) /// **GERALD RHEMANN AND MICHAEL JÄGER**

SHARPLESS 2–129 IN CEPHEUS (4-inch Borg apochromatic refractor at f/4, DTA Scientific Instruments Chroma C3 CCD, Astrodon filters, HαRGB image with exposures of 120, 20, 20, and 20 minutes, respectively) /// **PAOLO CANDY**



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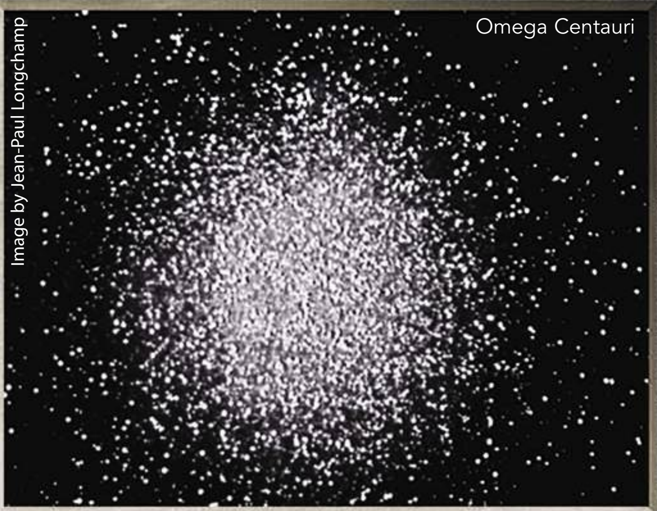
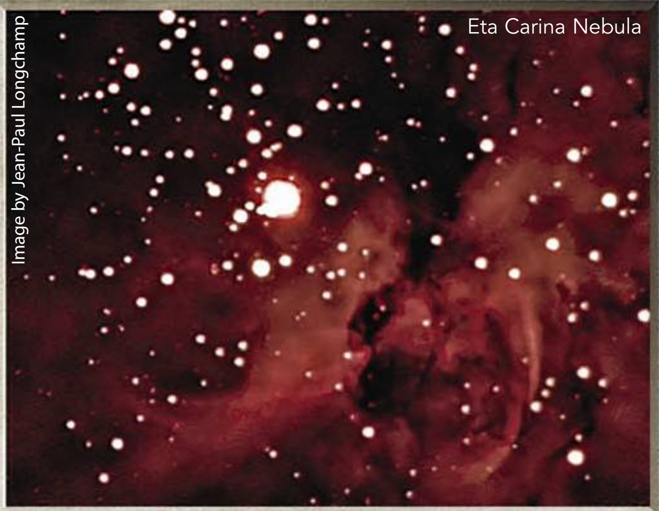


Meade 10" Schmidt-Cassegrain at f/10, 272 frames x 10 seconds.



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